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# ESTIMATING WATER QUALITY BENEFITS

Development Planning and Research Associates,
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prepared for
Environmental Protection Agency

August 1974

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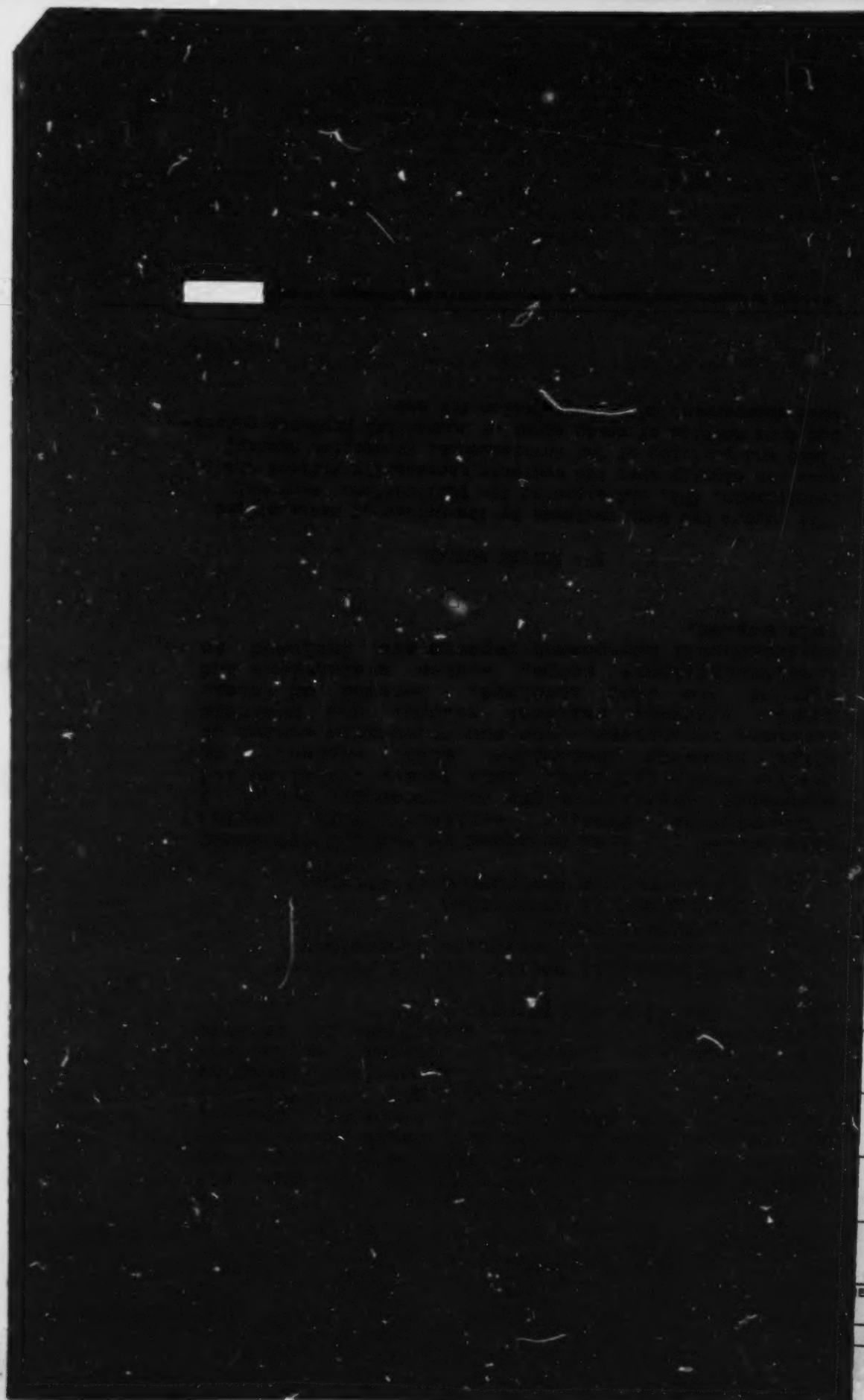

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| SELECTED WATER RESOURCES ABSTRACTS<br>INPUT TRANSACTION FORM | 1. Report No. | 2. | 3. Accession No.<br>W |
|---|---|---|---|

4. Title

Estimating Water Quality Benefits

5. Report Date

6.

8. Performing Organization Report No.

7. Author(s)

David L. Jordening, Development Planning and Research Associates, Inc., Manhattan, Kansas

10. Project No.

21-AQJ-05

11. Contract/Grant No.

68-01-0744

12. Sponsoring Organization

13. Type of Report and Period Covered

Environmental Protection Agency report number, EPA-600/5-74-014, August 1974

The objective of this report is to present a state of the arts summary concerning estimating water quality associated benefits. This summary is viewed as a useful administrative tool to those that have been assigned the task of directing current and future research activity.

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*Economic analysis, water quality, cost-benefit analysis, *benefit assessment, *literature search

| 19. Security Class (Report) | 21. No. of Pages<br>89 | Send To:<br>WATER RESOURCES SCIENTIFIC INFORMATION CENTER<br>U.S. DEPARTMENT OF THE INTERIOR<br>WASHINGTON, D.C. 20240 |
|---|---|---|
| 20. Security Class (Page) | 22. Price<br>4.75/225 | |

Dennis P. Tihansky | U.S. Environmental Protection Agency

EPA-600/5-74-014
August 1974

# ESTIMATING WATER QUALITY BENEFITS

by

David L. Jordening

Contract No. 68-01-0744
Project 21-AQJ-05
Program Element 1BA030

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U. S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D C. 20460

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## ABSTRACT

The objective of this report is to present a state of the arts summary concerning estimating water quality associated benefits. This summary is viewed as a useful administrative tool to those that have been assigned the task of directing current and future research activity.

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This report was submitted in fulfillment of Project Number 21-AQJ-05, Contract Number 68-01-0744 by Development Planning and Research Associates, Inc., Manhattan, Kansas, under the sponsorship of the Environmental Protection Agency. Work was completed as of April, 1974.

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# SECTION I

# NATURE AND OBJECTIVES OF THE REPORT

## A. INTRODUCTION

Recent public concern for environmental quality management and the accompanying deluge of literature on the subject would seem to indicate that the topics of resource conservation and the optimal utilization of renewable and nonrenewable natural resources are areas of concern that have not been explored until very recently. This, however, is not the case in that economics has long been concerned with a wide diversity of topics related to the maximization of temporal social welfare which encompasses many specific topics directly or indirectly related to resource allocation, and the optimal extraction and utilization of both renewable and nonrenewable resources. For example, an article entitled "The Economics of Exhaustible Resources," authored by Harold Hotelling was published in 1931 (Hotelling).

It is true, however, that most of the previous endeavors have not been overly concerned with resource utilization and conservation of resources as affected by pollution. The general area of environmental protection or environmental quality management has inevitably been overshadowed by other material welfare topics such as unemployment and the general oscillations in business activity. These topics have occupied or enjoyed a higher social and academic priority than the implications of alternative waste disposal practices.

In this regard the recent environmental management movement has provided the impetus for additional work on quality of life considerations which are intrinsically related to prevailing production techniques and practices (including both on-site and off-site waste disposal practices). This effort has also resulted in the recognition of the need to ascertain optimum surface water qualities which will complement social welfare maximization objectives which again encompasses both tangible and intangible considerations.

These renewed and increased efforts have resulted in a variety of suggested remedies which range from zero emissions to zero control. The suggested remedy is in part determined by whether one is the emitter or the recipient of pollution and there have been strong arguments for both extremes.

The deluge and diversity of suggested remedies has created a dilemma for those that have been assigned the responsibility of selecting and implementing appropriate environmental protection measures. It is desirable that the ultimate pollution abatement strategy be selected on the basis of the net social benefit derived. Unfortunately, due to the fact that estimating benefits of water quality enhancement per se is a relatively new area of endeavor with many inherent complexities, the selection of the appropriate strategy at the present time must be made on rather preliminary and tenuous information at best.

A sizable portion of the effort that has been devoted to estimating the net benefits of water quality enhancement has been problem, project and crisis oriented in nature. Many studies have been concerned with the unique problems associated with small and sometimes isolated and atypical geographical areas. This type of approach has lead to the development of a variety of methodologies and techniques that have been designed to assess the economic impacts of a variety of specific pollutants and regional water quality management problems. While many of these studies provide insight into the benefits of water quality management for a specific region, it is nevertheless frequently difficult to assimilate the results into a national net benefit estimation framework.

The diversity of methods, techniques and results makes it desirable to periodically engage in a state of the arts assessment to insure that the overall direction or approach of national policy is consistent with the results of numerous research projects. Such a state of the arts assessment is further desirable so that specific areas requiring additional research or refinement can be isolated and supportative research measures instituted.

## B. OBJECTIVES

The literature review that has preceded this report has clearly indicated that the general area of greatest need is that of estimating the benefits of water quality enhancement. For this reason this report will address the specific objective of providing a state of the arts assessment of the success of past endeavors that have been concerned with estimating the benefits of water quality enhancement and will not address other facets of water quality management, e.g., cost of pollution abatement.

## C. METHOD OF APPROACH

The value of water is determined by use. Any value reduction or use impairment can therefore be associated with the presence of one or more undesirable water quality constituent or characteristic. One way to approach the state of the arts assessment is therefore to present a benefit summary by specific pollutant by beneficial use. Intuitively the approach is appealing and straightforward but nevertheless possesses several limitations.

The first limitation encountered is that of developing a meaningful beneficial use taxonomy. A broad classification scheme -- such as the one used -- is admittedly overlapping and not mutually exclusive. On the other hand a highly refined or disaggregated system rapidly becomes too cumbersome to handle. The taxonomy selected incorporates four broad categories, i.e., esthetics, ecological, production and health. The complete beneficial use taxonomy to be used to structure the state of the arts assessment is presented below.

I. Esthetics
    - Esthetic enjoyment
    - Recreation
        - Contact recreation
        - Non-contact recreation
    - Property values

II. Ecological

III. Human Health

IV. Production
    - Municipal pre-use treatment
    - Domestic uses
    - Agriculture
    - Commercial fishing
    - Power generation
    - Navigation
    - Food and kindred products
    - Textile mills
    - Lumber and wood products
    - Paper and allied products
    - Chemical and allied products
    - Petroleum and coal products
    - Rubber and plastics
    - Leather
    - Stone, clay and glass
    - Primary metal

A brief explanation of the above beneficial use taxonomy is presented below.

Esthetic Benefits - include pecuniary and non-pecuniary benefits which result from greater esthetic enjoyment of surface water. Representative examples would include contact recreation, non-contact recreation, property values and other esthetic benefits. Many of these non-pecuniary benefits are difficult to quantify due to the complications associated with converting non-pecuniary benefits into economic terms.

A variety of techniques and concepts have been developed in an attempt to quantify intangible, non-monetary benefits. These include concepts such as option demand and latent demand which are designed to quantify various benefits of water quality enhancement.

Other benefits such as physic benefits would also be included in the above category. Additional methodological refinements are required before all esthetic benefits of water quality enhancement are quantified.

Ecological benefits of water quality enhancement include damage reductions to the ecosystem that do not directly or initially affect recreational usage or the above mentioned esthetic benefits. In some respects this category is a residual category which exists primarily due to the fact that we can not accurately assess in monetary terms the value of each component of the ecosystem to human welfare.

Human health benefits include all direct and indirect benefits that accrue as a result of environmental quality enhancement. This would include reduced medical expenses, increased efficiency, reduced sick days, reduced mortality and reduced health risks associated with water borne diseases or epidemics. While these benefits are difficult to quantify, there is evidence which indicates that they do in fact exist.

Production benefits include reduced damages and increased efficiency in all production processes which utilize water. This includes but is not limited to reduced scaling, reduced corrosion and increased efficiency of water as a productive imput.

A cursory survey of the above classification scheme quickly reveals that there is--at best--a very fine distinction between many of the major and minor items listed. For example, as defined herein esthetics includes, one, esthetic enjoyment not related to recreational activity, two, recreational usage of surface water bodies (both contact and noncontact water based recreation)and, three, property value benefits. However a rather fine and illdefined line exists between

esthetic enjoyment and noncontact recreational activity such as hiking or sightseeing.

Property value changes due to water quality changes are also related and intrinsically tied to esthetic appreciation of surface water. This problem, however, is not a major obstacle in that the above taxonomy therefore serves only as a broad general guide which is useful to expedite and organize the discussion.

It should also be obvious from the beginning that there is a great disparity in the degree of detail that can be presented in the state of the arts assessment by beneficial use. A great deal has been written in reference to water quality enhancement and recreation but very little has been done to quantify the ecological benefits of water quality enhancement.

The major emphasis of the report will be confined to a discussion of the first major categories or beneficial uses with less effort devoted to the remaining areas. It is also expedient to emphasize that the documentation will be confined to completed and published studies. It is recognized that there are perhaps several ongoing or recently completed studies that have not been included in the discussion herein. Only the passage of time, acceptance and finalization of recently completed and on-going studies can correct this deficiency.

In some cases it is not possible to consider the affects of individual pollutants separately. For example, the lethal dosage or toxicity level of various pollutants on aquatic life is determined by not only the concentration of the toxic substance but also the prevailing water temperature, dissolved oxygen level, season of the year and the life cycle of the affected species. Another example is sediment. Sediment is normally viewed as harmful to aquatic life, recreational activity, esthetic appreciation, and other withdrawal and nonwithdrawal uses of water. However, sediment reduction and reduced turbidity does not always produce a benefit. Reduced turbidity allows greater sun penetration resulting in increased algae blooms if sufficient nutrients are present. Sediment also absorbs taste and odor producing materials as well as reducing water-borne nutrients by entrapment. The reduction or elimination of one pollutant may therefore be accompanied by increased problems associated with other pollutants.

By considering the specific pollutants individually, important syngeristic effects are overlooked. At this point in time, however, it is not desirable or expedient to become overly concerned with complex synergistic effects when there is much to be learned about the damaging influences of specific pollutants considered individually. It would also be desirable to distinguish

between natural and man-made pollutants. In most cases, however, the state of the arts is such that it is not possible to make the additional refinement or distinction.

Even though there are obvious limitations, much can be gained by providing a state of the arts assessment of estimating water quality associated benefits by specific pollutant by beneficial use. The primary objective is to provide a brief summary of the state of knowledge concerning the benefits of water quality enhancement. This also includes a brief evaluation of the adequacy of the data and methodologies employed in acquiring the respective benefit estimates. This summary is viewed as an administrative tool to guide and direct future research activity and is not intended to be a comprehensive critique of currently employed methodology, theory and data.

## D. PROCEDURES EMPLOYED

In view of the breadth of the subject matter involved, it is instructive to briefly describe the procedures employed in the literature search so as to provide the reader with some insight into the thoroughness of the final product.

The search for empirical benefit estimates of water quality enhancement was initiated by consulting a recently compiled bibliography containing approximately 4,000 entries of current water related publications. The complete bibliography will be published by EPA under separate cover. This bibliography along with the "Cost Analysis of Water Pollution Control," (Dr. Tihansky, EPA) represents one of the most complete and up-to-date available.

Attempts were employed to acquire and review all listings relevant to the area of endeavor. This procedure further isolated other relevant publications that were not initially included in the bibliography. Other procedures such as literature searches were also provided by the National Technical Information Service and the Smithsonian Science Information Exchange. Additional contacts were made with qualified researchers and in this regard the services of Dr. Tihansky of EPA, Economic Analysis Branch, Implementation Research Division, were particularly valuable. All of the information acquired by these procedures was critically reviewed by DPRA staff members. It is believed that the above efforts have been successful in isolating most of the relevant publications containing empirical estimates of water quality associated benefits. In view of the vast amount of literature related to water quality and water quality management, it is possible, and indeed quite likely, that several relevant publications have ben inadvertently overlooked even though efforts were employed to produce a comprehensive product.

## E. ORDER OF PRESENTATION

The state of the arts assessment of water quality associated benefits is initiated with a discussion of the beneficial use that is believed to be the singularly most important source of monetary benefits from water quality enhancement--recreation. This discussion is followed by a summary of other beneficial uses--esthetics, property values and ecological.

An attempt has been made to present the results of each section in a brief and concise manner which will be useful to administrators in their attempts to direct further research activity to areas which currently need further research or additional refinement.

## SECTION II

## RECREATIONAL BENEFITS OF WATER QUALITY ENHANCEMENT

### A. INTRODUCTION

A tremendous quantity of literature has been published on the economics of water based recreation. Past and projected demand trends indicate that water based recreation has been, and will be in the foreseeable future, the outlet for increase leisure time activity and personal consumption expenditures (84, 11, 61, 85). Increasing demand for this activity further reiterates the need to quantify the economics of pollution and recreation. The possible elimination or reduction of this leisure time activity must be explored.

The importance of recreational benefits relative to the total benefits of water quality enhancement is supported by the results of various studies that have undertaken the task of quantifying the areal benefits of water quality enhancement. Such studies invariably conclude that recreational benefits are the largest single source of direct monetary benefits (85, 64, 10, 79). This beneficial use has been estimated to comprise as much as 75 percent or more of the total benefits of water quality enhancement (85, 10).

Others have succinctly summarized the importance of water based recreational activity and water quality by stating that the justification of pollution abatement measures may well hinge on the ability to quantify recreational benefits (63).

It is therefore only fitting that a major portion of the state of the arts summary be devoted to a discussion of recreational benefits of water quality enhancement. Another reason for initiating the report with a discussion of recreational benefits of water quality enhancement is that several other very closely related beneficial uses that have received less emphasis are at least partially covered in the recreation discussion, i.e., esthetic and ecological benefits.

One difficulty that is immediately encountered that adds to the breadth of the problem is that water based recreational activity includes a diverse number of activities that require various water quality standards. Water based recreation as defined herein includes activities such as swimming, boating, hiking, sport fishing, camping, sightseeing, and other activities.

The state of the arts assessment of the estimation of recreational benefits of water quality enhancement is perhaps best presented in a multiphase format. Considerable insight into the number of relevant factors that must be included is provided by first presenting a list of hypothesized use-quality relationships, i.e., hypothesized relationships between specific pollutants and water quality characteristics that can potentially limit or deter recreational activity or the pleasure experienced therefrom. The second step is to present documentation of specific damages and established critical levels based on either reported damages or expected damages as established by various use-quality relationships derived from environmental assessments and laboratory experiments. The third and final step is to present and evaluate economic studies that have attempted to quantify in economic terms various recreational use-quality relationships.

By approaching the problem in this manner the reader is provided with: one, a listing of potentially damaging pollutants; two, a listing of reported damages; and three, a list of studies that have quantified the damages or benefits of water quality enhancement in economic terms. This format also provides considerable insight into those areas that have been researched and further identifies those use-quality relationships that have not been quantified as of this time in economic terms.

## B. HYPOTHESIZED RELATIONSHIPS

It is relatively easy to hypothesize that a particular pollutant is damaging or that it influences a particular activity with or without providing the basis for the hypothesized relationships. Most hypothesized relationships presented in the literature do, however, possess at least some theoretical justification or foundation. Exhibit II-1, Water Characteristics or Constituents Detrimental to Water Based Recreational Activity, is presented with the expressed purpose of providing insight and documentation into the number of relevant pollutants that are potentially detrimental to water based recreation. All of the articles or references included in Exhibit II-1 have been reviewed and have been found to include the use-quality relationship as presented. It should be emphasized that Exhibit II-1 is <u>not</u> intended to be a comprehensive summary of all publications that have purported specific relationships but should be viewed as <u>only</u> a representative selection of studies that have suggested use-quality relationships. The inclusion of additional studies would, in all likelihood, merely increase the number of references by specific pollutant. There is, of course, the possibility that a few more specific pollutants would be added to an already rather lengthy list.

Exhibit II-1. Water Characteristics or Constituents Detrimental to Water Based Recreational Activity

| Characteristic or Constituent | Reference Number */ |
|---|---|
| **Physical:** | |
| Clarity | 8, 83, 126, 3, 7, 84, 40 |
| Color | 8, 117, 126, 3, 85, 10, 40, 121, 130, 76 |
| Odor | 8, 117, 126, 3, 64, 40, 121, 130 |
| Temperature | 8, 114, 117, 126, 3, 11, 85, 10, 40, 121, 130, 76, 78, 120 |
| Turbidity | 8, 117, 126, 84, 2, 85, 10, 121, 130, 76, 78, 120 |
| Sediment | 8, 3, 84, 2, 40, 76, 78 |
| Floating solids | 126, 40, 121 |
| TSS**/ | 117, 2, 85, 121 |
| Foam, slime, and scum | 8, 117, 126, 11, 40, 130, 78 |
| Algae | 8, 117, 3, 7, 11, 40, 121, 130, 76, 118, 78 |
| Weeds and plants | 8, 117, 126, 3, 7, 11, 40, 78 |
| Litter and debris | 8, 117, 126, 3, 7, 84, 11, 40 |
| **Microbiological:** | |
| Coliforms and other organisms | 8, 19, 42, 52, 46, 5, 117, 126, 3, 84, 85, 10, 40, 121, 76, 118, 78, 120 |
| **Inorganic:** | |
| Pesticides | 8, 117, 3, 40, 121, 78 |
| Herbicides | 117, 121 |
| Hardness | 3, 85 |
| pH | 75, 117, 11, 2, 85, 10, 40, 121, 78, 120 |
| TDS | 117, 85, 121, 130, 76, 120 |
| Nutrients (nitrogen and phosphates) | 8, 117, 3, 11, 2, 85, 40, 121, 1, 130, 118, 78, 120 |
| Toxic substances ***/ | 114, 117, 3, 115, 40, 121, 130, 76 |
| Phenols | 40, 121, 1, 76, 118, 120 |
| Other inorganics | 8, 3, 2, 85, 40, 121, 130, 76, 118, 78 |

Exhibits II-1. (continued)

| Characteristic or Constituent | Reference Number |
|---|---|
| Organic: | |
| BOD | 117, 85, 115, 10, 79, 40, 121, 130, 33, 120 |
| DO | 75, 117, 11, 2, 85, 64, 10, 40, 121, 78, 120 |
| Oil and gasoline | 8, 117, 126, 3, 10, 40, 121, 1, 78 |
| Organic poisons | 117, 115, 121 |
| Other organics | 8, 3, 40 |
| Radioactivity | 11, 61 |
| Taste | 117, 121, 130 |

*/ Reference numbers refer to the numerical listing of references at the end of the report.

**/ Includes settable solids.

***/ Includes heavy metals.

The conclusion that must be reached, however, at this rather premature point is that there are many specific pollutants that have been hypothesized as potentially detrimental to water based recreational activity. Some of these use-quality relationships would not be sufficiently important to result in use avoidance or substantially alter the recreational experience of the participant but do possess the potential for decreasing (perhaps only slightly) the quality of the recreational experience.

## C. REPORTED DAMAGES

The second step is to present a listing of documented damages or impacts by specific pollutant. This information is presented in Exhibit II-2. The basis for inclusion in this exhibit is that reference has been made to reported damages or concentrations of specific pollutants at which damage may reasonably be expected--based on actual water quality analysis or laboratory simulation of environmental conditions. Again the exhibit must not be viewed as a comprehensive listing of all reported damages or critical levels at which damage may be expected but rather a representative listing.

One final word of caution is perhaps appropriate at this point. Some of the studies were not intended to relate damages by specific pollutants to beneficial uses as classified herein. Some extensions were therefore required. For example, several studies have referenced specific levels of nutrients at which algae blooms may be expected. In view of the fact that other studies have documented that perceptible algae growths are undesirable and are responsible for nuisance conditions that have the potential of deterring recreational activity or reducing the pleasure of the recreational experience, the specified nutrient levels associated with algae blooms have been viewed or interpreted as reported damages.

The conclusion that must be reached is analogous to the results derived by reviewing Exhibit II-1. That is, there are many pollutants that can and have influenced either expenditures or participation in water based recreational activity or can, in some way, reduce the satisfaction derived from participating in water based recreational activity.

Several representative examples and further documentation of established damage levels or damage thresholds referenced in Exhibit II-2 are also included as separate attachments in the Appendix of this report. It is possible that some of the established critical levels or damage thresholds can be traced back to arbitrary standards established by various agencies. In that there is considerable evidence that some established standards are not sensitive or responsive to actual water quality requirements, an attempt has been made to avoid this type of damage documentation.

Exhibit II-2. Reported Damages and Established Critical Levels by Specific Pollutant

| Characteristic or Constituent | Critical Level | Reference Number | Effect |
|---|---|---|---|
| Physical: | | | |
| Clarity | -- | 8, 94 | Undesirable physical characteristic deterring recreational activity |
| Color | -- | 8, 94 | " " |
| Odor | -- | 8 | " " |
| Temperature | 85°F | 76 | Undesirable physiological effect on swimmers |
| | Change of | | |
| | 3°F | 76 | Undesirable effect on fish and other aquatic life depending on species, life cycle and season of the year (See Attachment A, Appendix A) |
| | 4°F | 76 | |
| | 5°F | 76 | |
| | 1.5°F | 76 | |
| | | 33, 21, 73 99, 100 | Other undesirable attributes of temperature changes on recreational activity |
| Turbidity | -- | 2, 78, 35 | Reduced fish catches and undesirable effects of increased turbidity on recreational activity |
| Sediment | -- | 35, 73, 94, 99, 2 | Increased reservoir deposits, reduced fish catches and reduced recreational value of streams and reservoirs |
| Algae | -- | 8, 11, 80, 78, 99, 9 | Use avoidance, aquatic life effects and reduction in recreational value resulting in increased algae growth |
| Weeds and aquatic plants | -- | 78, 9 | Reduced usability of recreational water bodies resulting from aquatic weed and plant pests |

Exhibit II-2 (continued)

| Characteristic or Constituent | Critical Level | Reference Number | Effect |
|---|---|---|---|
| Microbiological: Coliform & Other | 200 FC/ 100 ml | 46 | Health risks associated with primary contact recreation in polluted waters |
| | -- | 19, 5, 11, 118 | " " |
| Inorganic Pollutants Pesticides | 0.5 ppm (endrine) | 16, 11, 33, 41, 21, 73 | Toxicity of pesticides affecting fish and other aquatic life including species change (See Attachment B, Appendix A) |
| pH | 5-9 | 76 | Acceptable range for contact recreation |
| | 6-9 | 76 | Acceptable range for aquatic life |
| | 6.7-8.5 | 76 | Acceptable range for aquatic plants |
| | Change of 0.1 | 76 | pH change of 0.1 of saline water has been shown to be fatal to some species of fish |
| | -- | 107 | Damages to recreational resources (See Attachment C, Appendix A) |
| Alkalinity | 20 mg/l | 78 | Water with alkalinity of 20 mg/l is low in fish and aquatic plant productivity |
| | 20-40 mg/l | 78 | Water with alkalinity of 20-40 mg/l is low to medium in fish and aquatic plant productivity |
| | 90 mg/l | 78 | Water with total alkalinity of greater than 90 mg/l has been shown to be high in fish and aquatic plant productivity |
| TDS | 1.5 g/l of NaCl | 76 | Concentrations of 50 millimoles (1.5 g/l of NaCl) have been shown to adversely affect aquatic plant life |

Exhibit II-2 (continued)

| Characteristic or Constituent | Critical Level | Reference Number | Effect |
|---|---|---|---|
| Inorganic Pollutants (continued) | | | |
| Boron | 1 mg/l - 15 mg/l | 76 | Inhibits growth of aquatic life |
| Cadmium | 0.01 mg/l | 76 | Inhibits growth of aquatic life |
| Chromium | 5 mg/l | 76 | Adversely affects plant life |
| Copper | 0.5 mg/l | 76 | Adversely affects fish life |
| | 0.1 mg/l | 76 | Adversely affects plant life |
| Lead | 0.5 mg/l | 76 | Adversely affects animal life |
| Sulfate & Sulfide | 1.0 - 25.0 mg/l | 76 | Lethal to some species of fish |
| Chlorophenol | .0001 mg/l | 61, 76, 118, 16 | Taints fish flesh. (See Attachment D & E, Appendix A) |
| Mercury | -- | 43 | Economic damage due to mercury scare including sport fishing |
| Other toxic substances | -- | 61, 115, 68, 20, 73 | Aquatic plant and animal impacts associated with toxic substances (See Attachment F, G, H, I and J, Appendix A) |
| Phosphorus | .015 mg/l | 118 | Critical level above which algae blooms may be expected |
| | .015 mg/l | 80 | Nuisance algae conditions may be expected |
| | 50 mg/l | 76 | Undesirable plant life can generally be expected to exist in water with greater than 50 m phosphorus |
| | -- | 11, 2, 16, 78, 94 | Reduced recreation value, lethal fish dosages, and nuisance condition have been associated with excessive concentration of phosphorus |

Exhibit II-2 (continued)

| Characteristic or Constituent | Critical Level | Reference Number | Effect |
|---|---|---|---|
| Inorganic Pollutants (continued) | | | |
| Nitrogen | 0.3 mg/l | 118 | Algae blooms may be expected |
| | -- | 94 | Reduced recreational value of surface water bodies resulting from excessive concentration of nitrogen |
| Nutrients (in general) | -- | 11, 80, 9, 94 | Reduced recreational value and usability associated with excessive concentration of nutrients |
| Organic Pollutants | | | |
| DO | -- | 2, 73, 100, 94, 9 | Undesirable effects on fish life and the general desirability of recreational water |
| BOD | 200-400 ppm | 61 | Odor problems associated with excessive BOD levels. (See Attachment K, Appendix A) |
| | 15 lb/acre /day (0.2 ppm/ day | 16 | Associated with oxygen deficient water |
| Oil | 50 gal/sq. mile | 76 | Perceptible water discoloration (See Attachment L, Appendix A) |
| | 5-50 mg/l | 76 | Toxic to some forms of wild life |
| | -- | 61 | Beach closings |
| | -- | 81, 89, 21 73 | Undesirable recreational impacts associated with oil pollution |

In addition to the reported damages and critical levels portrayed in the above exhibit, there is a group of researchers that have been concerned with quantifying public perception, attitudes and use avoidance associated with water quality degradation. While changing public attitudes and the reluctance to utilize surface water bodies for recreational purposes may not constitute a physical damage per se, the results are the same since reluctance to recreate or the reduced pleasure derived from recreating in polluted waters may result in decreased usage, reduced expenditures and a possible reduction in human welfare.

Several studies have attempted to quantify use avoidance, public awareness, perception and concern through the use of interview techniques. The results of these studies are depicted in Exhibits II-3 and II-4. Exhibit II-3 presents a listing of site user's concern of the possible detrimental effects of water pollution on boats, fishing equipment and aquatic life. Exhibit II-4 presents the results of several use avoidance studies. The latter exhibit presents the percentage of those interviewed that reportedly had or would curtail their recreational activities as a direct result of increased pollution.

The obvious question that now arises is, what has been done to quantify the above mentioned physical damages in economic terms?

## D. ECONOMIC ANALYSIS OF RECREATIONAL DAMAGES AND BENEFITS

Summarizing the economic studies in a manner similar to that employed above reduces the rather lengthy presentations to an astonishingly brief summary.

It appears that the deluge of literature on the subject has resulted in very few studies that have attempted to empirically quantify the economics of waste disposal alternatives. Coomber and Biswas have succinctly summarized their feeling concerning the success of the environmental movement in the following material.

"In recent years, the conservation movement has received support for environmental programs by virtue of its popularity among the public at large, and not independently with the media. The non-profit making, voluntary and sometimes heroic actions of a few concerned individuals, with their few perceptible achievements, have contrasted sharply with a deluge of literature issued on the subject. Rarely has a cause with such acclaim and documentation achieved so little." (23)

Exhibit II-3. Site user's concern of possible detrimental effects of water pollution on boats, fishing equipment and fish in nine Illinois lakes—*/

| Possible Effect of Water Pollution | Percent of Site Users Reporting Concern over the Possible Harmful Effects of Pollution on Boats, Fishing Equipment and Fish |
|---|---|
| Water stains on boats | 81.1 |
| Rusts, corrodes, or rots boats | 86.2 |
| Dirt or deposits on boats | 69.5 |
| Wears paint on boats | 75.6 |
| Stains fishing equipment | 72.7 |
| Corrodes or rots fishing equipment | 100.0 |
| Dirt and deposits on fishing equipment | 100.0 |
| Reduces number of fish | 90.9 |
| Reduces size of fish | 95.9 |
| Affects taste of fish | 97.5 |
| Affects odor of fish | 90.8 |
| Makes fish undesirable to handle | 94.9 |

*Reference 3

**Exhibit II-4. Use avoidance or curtailed usage of recreational waters as a result of increased pollution**

| | General Recreation: Percent of site users interviewed reporting reduced recreational usage of surface waters*/ | Swimming: Percent Interviewed reporting specific pollutants that would deter swimming in surface water**/ |
|---|---|---|
| Unclean | 12.7 | 40 |
| Dirty | 19.1 | 40 |
| Odor | 14.9 | |
| Algae | 5.6 | 80 |
| Dead fish | 12.2 | |
| Litter debris | 10.7 | 40 |
| Weeds and plants | 7.7 | 40 |
| Fertilizer | 16.3 | |
| Soap and detergents | 8.6 | |
| Mud, silt or sand | 14.2 | |
| Sharp stones | 9.9 | |
| Glass | 7.3 | 70 |
| Oil, grease and gas | 8.1 | |
| Insecticides | 11.4 | |
| Chemicals | 30.1 | |
| Bacteria | 12.8 | |
| Sewage | 20.8 | |
| Manure or animal waste | 16.3 | 30 |
| Suds and foam | | 20 |

| | Percent Interviewed Reporting Use Avoidance***/ | | | |
|---|---|---|---|---|
| | Swimming | Water Skiing | Fishing | Boating |
| Pollution in general | 20 | 5 | 2 | 2 |

*/ Reference 3 (Study of use avoidance or curtailed usage of site users in nine Illinois Lakes.)

**/ Reference 29 (Study of specific pollutants potentially detrimental to swimming in Wisconsin Lakes.)

***/ Reference 126 (Percent of respondents indicating they would refrain from engaging in various water related activities in San Francisco Bay because of pollution.)

Exhibit II-5 presents a list of economic studies containing estimates of recreational damages or benefits by specific pollutant. The criteria for inclusion in the exhibit is restricted to those studies that contain estimates of recreational damages or benefits accompanied by the methodology employed to derive these estimates. It is recognized that there are numerous other estimates of the economic damage of pollution or estimates of the benefits of water quality enhancement that frequently appear in popular publications. While there is considerable value in this type of estimate, they cannot be evaluated without the knowledge of the methodology employed. For this reason, this type of estimate has not been included herein.

Prior to commenting on the methodologies utilized and the adequacy of the data of each study, it is perhaps expedient to summarize the above three exhibits into one concise summary which is intended to portray those specific areas that have been the subject of past studies and those areas presently lacking economic quantification. Exhibit II-6 clearly shows that even though there are numerous hypothesized damages and reported damages there are relatively few studies concerned with the economics of water quality degradation or enhancement.

## E. EVALUATION

Exhibits II-5 and II-6 include a total of eight studies that have in some way attempted to quantify in economic terms the recreational benefits or damages of water quality degradation or enhancement. There is, however, a great disparity in the methods adopted and the adequacy of the resulting estimates. Before one can ascertain the appropriate direction of future research, the adequacy of the data and methodology incorporated in existing studies should be discussed. For this reason a very brief evaluation of the above eight studies is presented below. This evaluation is not intended to be an indepth study or complete review of all theoretical and methodological considerations but is instead concerned with briefly reiterating <u>what</u> has been measured and <u>how</u> it has been quantified.

A variety of techniques have been proposed to measure or evaluate environmental intangibles in monetary terms. These include, but are not limited to, the following techniques and methods:

Exhibit II-5. Economic Studies of Recreational Damages and Benefits by Specific Pollutant

| Characteristic or Constituent | Reference Number */ |
|---|---|
| BOD | 10, 79 |
| DO | 115, 64 |
| Algae | 99 |
| Beach Improvement | 99 |
| Sedimentation | 35 |
| Temperature | 99 |
| Toxic Substances | 115 (kraft mill effluents only) |
| General Quality Indices | 85 |
| pH (acid mine drainage) | 59 |

*/

85. Nemerow, Nelson L. and Hisashi Sumitomo, Benefits of Water Quality Enhancement (Onondago Lake), Water Pollution Control Research Series, 16110 DAJ 12/70.

115. Stoevener, Herbert H., etal., Multi-Disciplinary Study of Water Quality Relationships: A Case Study of Yaquina Bay, Oregon, Oregon State University, Special Report 348, Feb., 1972.

64. Kneese, Allen V. and Stephen C. Smith, "The Social Value of Water Recreational Facilities Resulting from an Improvement in Water Quality: The Delaware Estuary," by Davidson, Paul, F. Gerard Adams and Joseph Seneca, from Water Research, Resources for the Future, Inc., 1965.

10. Bramer, H. C., The Economic Aspects of the Water Pollution Abatement Program in the Ohio River Valley, Ph.D. Dissertation, University of Pittsburg, 1960.

79. Matson, Jack V., "Cost of Industrial and Municipal Water Pollution Abatement in the Maumee River Basin," MS Thesis, University of Toledo, January 1968.

35. Dow Chemical Co., Midland, Michigan, "An Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization (C-1677), Final Report Feb. 15, 1971 - Feb. 14, 1972.

Exhibit II-3 (continued) footnote s

99. Reiling, S. D., et al., "Economic Benefits from an Improvement in Water Quality," Office of Research and Monitoring, U.S. EPA, EPA-R5-73-008, January, 1973.

59. Kinney, Edward C., "Extent of Acid Mine Pollution in the United States Affecting Fish and Wildlife," U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Circular 191, 1964.

Exhibit II-6. Summary of Hypothesized, Documented and Economic Appraisal of Water Quality Associated Recreational Benefits and Damages by Pollutant

| | Hypothesized Relationships | Documented Damages | Economic Analysis Reference No. |
|---|---|---|---|
| Physical: | | | |
| Clarity | X*/ | X | |
| Color | X | X | |
| Odor | X | X | |
| Temperature | X | X | 99 |
| Turbidity | X | X | |
| Sediment | X | X | 35 |
| Floating solids | X | X | |
| TSS | X | X | |
| Foam, slime and scum | X | X | |
| Algae | X | X | 99 |
| Weeds and plants | X | X | |
| Litter and debris | X | X | |
| Microbiological: | | | |
| Coliform and other organisms | X | X | |
| Inorganic: | | | |
| Pesticides | X | X | |
| Herbicides | X | X | |
| Hardness | X | X | |
| pH | X | X | 59 |
| TDS | X | X | |
| Nutrients | X | X | |
| Toxic substances | X | X | 115 (kraft mill effluent only) |
| Other inorganics | X | X | |
| Organic: | | | |
| BOD | X | X | 10, 79 |
| DO | X | X | 115, 64 |
| Oil and gasoline | X | X | |
| Other organics | X | X | |
| Radioactivity | X | X | |
| Taste | X | X | |
| General Water Quality Indices | | | |
| Pollution Index | X | X | 85 |

*/ Recreational use-quality relationships (hypothesized and documented) previously discussed and presented in Exhibits II-1 and II-2 are denoted by X's.

Willingness to Pay
- Hotelling-Trice-Wood Method
- Clawson's Method
- Consumers' Surplus
- Non-discriminating Monopolist

Expenditures Method
Cost Method
Gross National Product
Value Added

While the above list is not exhaustive, it does include most of the methods currently employed. The problem that is encountered is that some studies (some successfully and others unsuccessfully) incorporate several of the above techniques in various segments of the analysis and consequently a classification of studies by methodology employed is again difficult.

It is also obvious that as of this time there is not complete unanimity concerning the technique that should be employed in quantifying water quality associated benefits. Should the Clawon method which utilizes site-user data be utilized to construct the recreationalist's demand function or are other methods which utilize nonuser data preferred? The results are not analogous (101). Is the relevant portion under the demand curve the maximum revenue of the non-discriminating monopolist or is the consumer's surplus to be included? These are a few of the methodological controversies that are still being debated at this time.

This lack of agreement is partially explained by the fact that some authors are concerned with quantifying the value of recreation in very small and perhaps isolated regional economy while others are concerned with the impacts of larger and more diverse geographical areas. The major reason for the source of controversy, however, stems from the fact that quantification of the benefits of water quality enhancement involves assigning values to or measuring intangible, incommensurate factors. This requires the development of appropriate techniques designed to circumvent the problem which inevitably leads to further discussions of the relative merits of alternative techniques.

It is also expedient to mention at this point that few have undertaken the task of systematically estimating national recreational benefits of water quality enhancement. Factors such as the substitution phenomenon (areal substitution within water based recreation and substitution within other nonwater based recreational activities) may be expected to intensify the methodological controversey.

Without further elaboration, we shall briefly comment on the adequacy of the above mentioned studies which is followed by a concise summary statement concerning the current state of the arts of estimating recreational benefits of water quality enhancement.

Onondaga Lake (85)

The Onondaga Lake study entitled "Benefits of Water Quality Enhancement" resulted in an estimate of the benefits of improved water quality in Onondaga Lake at 4.4 million dollars, most of which consist of recreational benefits (3.7 million dollars). The recreational benefits included those derived from increased fishing and general recreational activity.

The technique employed is essentially a comparative demand analysis, i.e., estimating direct expenditures at the existing water quality and at a higher water quality with the difference being entitled net annual measurable social benefits for Onondaga Lake at improved water quality. This is a rather unfortunate use of terminology in that the term net benefits is normally net of the cost of pollution abatement which is not reflected in the "net benefit" number derived.

The specific procedures employed, i.e., decaying demand functions associated with greater distance and per capita unit demand adds a distinct Clawson flavor to the study.

While the above study is one of the few that undertakes the unprecedented task of empirically estimating a wide variety of benefits of water quality enhancement, there are several features that limit its usefulness. First, the study quantifies only the direct expenditure incurred in the pursuit of recreational activity. Second round influences are not included. Secondly, the procedures utilized to estimate the recreational demand at the present water quality and at improved water quality are not sufficiently specified. Other authors have explored and utilized more sophisticated and highly specified recreational participation models which we believe are preferred on the basis that a more detailed explanation of the recreationalists behavior results. An additional criticism, in no way unique to this study, is that only direct monetary benefits are considered. The authors do not explore the possibility of estimating option demand, latent demand, time spent in travel, time spent recreating, or secondary effects of increased expenditures. The simplistic demand functions developed possess value but can not and were not represented as anything more than a partial quantification of direct monetary benefits of water quality enhancement. It is believed that these features are serious enough to prevent the results to be construed as being accurate measures of the net social benefits of water quality enhancement.

Yaquina Bay (115)

The Yaquina Bay study, (115) provides an example of attempts to develop a more adequate methodological base to estimate the benefits of alternative waste disposal practices. The methodology developed incorporates the input from several disciplines to explain the biological and economic effects of pollution. This is accomplished by constructing a biological production function responsive to increased pollution which also influences angling success and therefore angling behavior.

The use of input-output procedures also provides an excellent way of quantifying the interindustry relations and impacts of recreational expenditures on the local community. The portion of the report concerning the interpretation of the economic alternatives associated with waste disposal is unique and far superior to any other study reviewed in that it clearly and adequately discusses various economic alternatives. In summary, the biological aspects of pollution, recreational demand specification and estimation with and without pollution, explanation of the area economic structure and the economic interpretation of the results are clearly preferred to most existing studies concerned with the recreational impacts of waste disposal.

Due to the fact that the geographical area studied possess a highly specialized recreational resource and only the monetary effects of kraftmill effluent on sport fishing were explored; there is only limited appliability to other geographical areas.

Delaware Estuary (64)

The Delaware Estuary study -- perhaps the most comprehensively studied basin in the U.S. -- provides a third source of benefit estimates. This particular area is one of the most heavily populated and polluted areas of the country. As a result, the basin has been the source of a great deal of water quality management research.

The Delaware Estuary study provides a good illustration of how cost-sensitivity analysis can be applied to alternative goals and further provides a rigorous mathematical representation of waste assimilative and transport capacity of the estuary. The various objective functions consider the source and impact of a large number of pollutants. The concern here, however, is confined to the contributions of the study to estimating recreation benefits.

In this regard the Delaware estuary study considers the influence of dissolved oxygen levels on recreational activity. The major contributions lie in the highly specified recreation participation model indicating a large latent recreational demand. Beyond this, however, its contributions concerning estimating recreational benefits are quite limited. The benefit values derived are based on ascribed values (from $1 to $5) for an additional recreational day's activity resulting from water quality enhancement.

It therefore appears that its contribution to empirical recreational benefit estimation are rather limited with the exception of the recreation participation model and the latent demand concept.

Ohio and Maumee Basins (10, 79)

Studies by Bramer and Matson provide another source of empirical estimates of recreational benefits. Both of these studies are concerned with the benefits associated with primary and secondary waste water treatment and associated BOD reduction. The technique utilized to estimate the benefits of water quality enhancement is the total expenditure method. Bramer's assumptions concerning recreational benefits of water quality enhancement are not highly refined. The inauguration of secondary treatment is assumed to increase recreational expenditure by 50 percent. The basis of this assumption is not well specified and may be questioned. While the study was a pioneering effort it is in need of additional refinement.

The study by Matson incorporates similar assumptions and methods as employed by Bramer and therefore makes no additional contribution to benefit estimation but does provide an estimate of recreation benefits for another geographical area.

Other Studies

The effects of sediment on recreation have been estimated in "An Economic Analysis of Erosion and Sediment Control Methods for Watersheds Undergoing Urbanization," by the Dow Chemical Company. Recreational benefits are estimated by projecting the number of recreationalists and estimating the present value of benefits per ton of sediment removed. While the major portion of the paper is concerned with engineering aspects of sediment control, it is one of the only estimates of benefits of sediment removal and therefore has considerable value. Various features of the study could be (with slight modification) applied to other hydrologic regions.

A publication sponsored by the Office of Research and Monitoring, U.S. Environmental Protection Agency, entitled "Economic Benefits from an Improvement in Water Quality," provides empirical estimates of the benefits of algae removal, temperature reduction and beach improvement. The estimates of recreational expenditures with and without water quality improvement provides an opportunity to estimate the benefits of water quality enhancement using the consumer surplus method. Both primary and secondary effects of increased recreational expenditures are provided for the case study area -- Klamath Lake, Oregon. In general, the methodology and data appears to be much more comprehensive and well specified than most of the previously discussed studies. Even the latter study is concerned primarily with estimating the demand shifts resulting from water quality enhancement but does not consider complex substitution and many other factors which may be expected to change as water quality in this lake and other surface water bodies improves.

The last benefit estimate is that provided by the U. S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife. This estimate is derived by inventorying the extent of acid mine damage and assigning utilization and daily expenditure data to obtain estimates of national recreational benefits to be realized from the restoration of acid mine waters.

## F. SUMMARY

The evaluation of the feasibility of environmental policies and controls will, in all likelihood, be couched in traditional benefit cost framework. Since the implementing agency is a federal agency and the costs of control are at the present time formulated in terms of national costs in the form of various national water bills, it is desirable that the benefits of water quality enhancement be formulated in a similar manner to achieve the required comparability of benefits and costs. It is therefore expedient to briefly evaluate the existing work on estimating water quality benefits in terms of their contributions to deriving national benefit estimates. This type of summary or evaluation is somewhat unfortunate in that all of the above economic studies have (with the exception of reference 59) addressed the question of <u>regional</u> benefits of water quality enhancement. Notwithstanding, the urgency of acquiring national benefit estimates requires that such a summary be undertaken so as to focus more sharply on areas requiring additional research.

As has been previously stated, many (indeed most) studies concerning water based recreation are concerned with water availability or water quantity as opposed to water quality. A sizable portion of the remaining studies is concerned with evaluating water quality standards that have been adopted by various state, local or federal agencies. Even within this group of studies, there is considerable controversy. While many researchers conclude that there is little relationship between established standards and the occurrence of actual damages, there are also those who prefer restrictive standards based on potential risks as opposed to actual damages. In the area of establishing national standards, there is even more controversy due to the geographic variation in the effects of various pollutants due to differential effects of various hydrologic and climatic conditions. While it is not the purpose herein to engage in a long discussion of the merits of existing or established standards, the controversy encountered is indicative of the entire area of water quality management.

Considerable attention has also been devoted to various methodological aspects of estimating water quality associated benefits and damages (114, 117, 86, 72, 51, 124, 85). The results are inconclusive. There is little agreement on the appropriate methodology to be employed in estimating water quality associated benefits, e.g., is the consumer surplus or the nondiscriminating method more appropriate. There does, however, appear to be some evidence that the consumer surplus method is gaining in popularity as a method to be used in assessing regional benefits of water quality enhancement (99, 115). Few have attempted, however, to expound on the applicable methodology for estimating national recreational benefits of water quality enhancement. While little has been done in this area, it is safe to say that techniques and methods applicable for regional studies are not equally **apropos** to the estimation of national water quality benefits without at least some alterations. The sum of the regional impacts is not necessarily the desired national estimate.

What then do the above cited economic studies contribute to the estimation of national water quality associated recreational benefits? Our opinion is that while the above studies have made many contributions to estimating the regional recreational benefits, they can not be used per se in the quest for national water quality associated benefits. The essential building blocks or foundations have perhaps been established.

The first reason is that all of the studies are incomplete, i.e., some essential considerations have been deleted from all of them. Their intent, in some cases, was to concentrate on only one facet of recreational benefits, e.g., sport fishing or some other beneficial use. Secondly, even those studies that attempted to estimate all benefits failed to include various factors. Recreational benefits of water quality enhancement encompasses much more than merely a subset of the monetary measurable benefits of water quality enhancement. Consideration should be given to option demand, latent demand, psychic income, second round effects and substitution effects. It is well recognized that the quantification of these factors is currently impossible, however, recognition of some of these factors is essential.

Still another factor limiting the usefulness of the above studies is that almost all of the above studies are problem, project and crisis oriented in nature and as such apply to the specific problems of specialized geographical areas, i.e., the problems associated with Yaquina Bay Klamath Lake are not typical of the nation as a whole. The generalization of the results may therefore be questionable. One study looks at sport fishing and another the benefits of algae removal. The benefits to the sport fishing industry in the Northwest may have little correspondence with the sport fishing industry of the Southeast. To further reiterate the point, the studies tend to be noncomparable and unique for several reasons. Some consider primary benefits only while others include secondary benefits. Others include only very crude and arbitrary benefit estimates while others include highly specified recreational participation models. Others look at only specific pollutants while some discuss the effects of pollution in general or utilize various pollution indices.

The studies as such are not amenable to aggregation but much can be gained by incorporating various features of each study into further research endeavors which are explicitly designed to estimate national recreational benefits of water quality enhancement. Regional studies have merit in themselves and efforts should be focused on extending the analysis on a national basis.

## G. RECOMMENDATIONS

Many of the limitations encountered seem to stem from the fact that as of the present time the research conducted has been rather piecemeal, problem, project and crisis oriented in nature. While much has been gained in the way of quantifying recreational participation and the effects of water quality enhancement for specific uses and areas, much could be gained by restructuring the emphasis to include the development of national estimates of the benefits of water quality enhancement. The scope of the national recreation benefit study must be expanded to consider in greater detail the complex behavioral and economic impacts associated with estimating demand shifts associated with multibasin water quality enhancement. The scope can not be couched in the traditional and simplistic demand shifts associated with water quality enhancement in a specific reservoir exogenous of other surface water bodies. Such a study must consider all water based recreational activities, second round effects and other concepts such as latent demand, option demand, esthetic satisfaction of the recreationalist and the substitution phenomenon. The study must also recognize from the inception that the objective is to derive national estimates of recreational benefits of pollution abatement and must therefore select representative areas for which the results can be generalized to acquire the desired national totals.

## SECTION III

## WATER QUALITY AND ESTHETICS

### A. INTRODUCTION

The results of the preceding section -- the inability or as some would say, the unwillingness of the economist to quantify recreational benefits or the damages of water quality degradation in monetary terms -- provides considerable insight into the results that can be expected in this section. This anticipated result stems from the fact that esthetics, like recreation, involves many intangible nonmonetary considerations that do not as such enter the market mechanism.

The beneficial use discussed herein -- esthetics enjoyment -- has been included as a subcategory or subset of the first major beneficial use. This section could be included in the recreation section previously discussed in that the beneficial use distinction is admittedly rather germane. In fact it is quite difficult at times to differentiate recreational benefits from esthetic benefits. For example, it is esthetically pleasing to fishermen and nonfishermen alike to view a cool, clear surface water body with a thriving trout population. Even the knowledge -- without intended use -- that such a stream exists provides the source of esthetic satisfaction.

Some may be inclined to differentiate on the basis of activity, i.e., activities which directly involve the use of surface water for recreation (swimming, boating, etc.) as opposed to activities such as sight-seeing where surface water may be only a secondary consideration. This criteria is not appreciably superior in that it is equally difficult to differentiate on this basis, i.e., the fisherman may derive greater satisfaction from the scenic or esthetic qualities of the area than from fishing.

There are, however, several studies that do not conveniently fall into the recreation category and are therefore classified as studies concerned with the general esthetic benefits of pollution abatement.

Attempts have been made to keep the format of this section similar to that utilized in the recreation section. There will, however, be deviations necessitated because of varying methodologies employed and differences in the state of knowledge.

## B. HYPOTHESIZED CHARACTERISTICS AFFECTING ESTHETIC SATISFACTION

The list of specific pollutants or water quality constituents potentially detrimental to esthetic satisfaction could conceivably include every known pollutant. The inclusion of the option demand concept virtually guarantees a lengthy list of specific pollutants that are potentially detrimental to esthetic satisfaction or appreciation.

One problem that is immediately encountered is that few authors have attempted to compile a complete list of pollutants capable of impacting esthetic appreciation. This is to be expected considering the evasive nature of esthetic satisfaction and the complexities encountered in their quantification. Since, however, esthetic appreciation and recreation are so closely aligned, the list of pollutants may include all of the hypothesized pollutants effecting water based recreation presented earlier. All of the pollutants included in the earlier exhibit affect aquatic life, wild life support potential or human usability or surface water bodies and therefore esthetic appreciation.

In addition to these factors, there are other considerations that influence the esthetic satisfaction derived from surface water bodies and natural resources in general. Many of these considerations include unique physical attributes associated with surface water bodies or the surrounding environs. Some of these factors are not directly related to water pollution but instead relate to other factors such as accessibility, historical value, urbanization, remoteness or other "indirect" consideration. These factors are, nevertheless, important considerations that must be appraised in ascertaining the value of natural resources which in turn may be affected by increased water quality degradation. These hypothesized characteristics and constituents are presented in Exhibit III-1. The documentation has been deleted from this exhibit in that they come from one of three other sources (i.e., reference 71, 31, 2).

It is recognized that Exhibit III-1 presents a slight deviation from the procedure established in Exhibit II-1 in that the latter exhibit includes many considerations other than strictly water quality factors.

The second step in the state of the arts assessment of recreation benefits and damages was to present a listing or summary of reported or documented damages. A comparable procedure was undertaken for esthetic benefits and damages of water quality enhancement or water quality degradation.

Exhibit III-1. Factors that Must be Considered in Assessing the Esthetic Value of Surface Water Bodies and Other Natural Resources

I. Physical

Water Quality Characteristics

- Clarity
- Color
- Odor
- Temperature
- Turbidity
- Sediment
- Floating solids
- TSS
- Foalm slime and scum
- Algae
- Weeds and plants
- Litter and debris

Other Physical Characteristics

- Drainage area
- Stream order
- Average gradient
- Total relief
- Average flood plain width
- Average valley height/average valley width
- Stream width
- Stream depth
- Stream velocity
- Bed material
- Floatability
- Invertebrates - total no.
- Invertebrates - diversity

Exhibit III-1 (continued)

II. Land Use Measures

Other Physical Attributes

- Forest cover
- Slopes
- Land use
- Remoteness
- Artificial controls
- Water supply and sewage plants
- Productive industry
- Extraactive industry
- Valley terrestial habitat
- Hillsides terrestial habitat

III. Esthetic Impression Measures

Including Natural and Man-made Considerations

- Visual pattern quality
- Land husbandry
- Degree of change
- Recovery potential
- Local scene
- View confinement
- Serenity
- Naturalness
- Geological values
- Historical values
- Diversity - flora and fauna
- Artificial controls (dams, etc.)
- Accessibility
- Vistas
- View confinement
- Utilities
- Urbanization

## C. DOCUMENTED ESTHETIC DAMAGES AND BENEFITS OF WATER QUALITY ENHANCEMENT

In the case of recreational benefits and damages of water quality enhancement, it was possible to construct a list of documented damages and specific pollutant levels at which damage could reasonably be expected. In the case of esthetic benefits and damages, it is exceedingly difficult to attach a specific level or concentration at which damage occurs. For example, how many pieces of litter are required before esthetic appreciation is reduced? What is the value of game fish relative to rough fish? There have, however, been several studies which have utilized interview techniques to ascertain percentages of participants that object to various natural and man-made attributes of or associated with the esthetic appreciation of natural resources.

Exhibit III-2 presents a list of unattractive features and the percentages of participants interviewed that find specific features objectionable. Several of the studies have been oriented to recreational usage of water, however, many of the undesirable esthetic attributes listed may well be displeasing to the nonrecreationalist as well.

Other undesirable esthetic considerations that concern recreationalists and other users of surface water bodies are listed in the Appendix of this report. These unappealing aspects include a variety of esthetic considerations reported by both users and nonusers, only a few of which are directly related to water quality. These characteristics have been assessed to determine public perception, attitudes and behavior in references 126, 7 and 27.

## D. ECONOMIC EVALUATION OF ESTHETIC QUALITIES OF WATER

The quantification of esthetic considerations of water quality enhancement is lagging even the quantification of recreational benefits. Most of the work at this time has been confined merely to ascertaining desirable and undesirable environmental impacts and has not at this time undertaken to quantify in monetary terms the esthetic benefits or damages. Any attempt to do so has -- out of desperation -- taken the approach of ascertaining the magnitude of the benefits needed to equal or exceed the benefits of a specific development project (62). While such an approach is understandable in

Exhibit III-2. Unappealing Esthetic Qualities Reported by Users and Nonusers of Recreational Areas

| Esthetic Characteristics | Percent Interviewed Indicating Unappealing Response to Specific Esthetic Factors */ |
|---|---|
| Water pollution | 51 |
| View | 8 |
| Water Characteristics (general) | 10 |
| Recreation opportunities | 5 |
| Climate | 6 |
| Commercial factors | 8 |
| Nothing in particular | 28 |
| Irrelevant responses | 4 |
| Water characteristics | 27.5 |
| Natural surroundings | 8.1 |
| Facilities and man-made surroundings | 17.7 |
| Opportunities for specific activities | 6.8 |
| Generally attractive or pleasant | 3.2 |
| Nothing | 62.5 |
| Unclear | 8.1 |
| Dirty | 14.2 |
| Bottom quality | 3.5 |
| Odor | 1.7 |
| Temperature | 1.7 |
| Too small | 1.2 |
| Too shallow | 2.5 |
| Weeds, plants, algae | 3.8 |
| Other pollutants | 2.5 |
| Surroundings | 1.3 |
| Lack of activities & facilities | 3.4 |
| Generally unattractive or unpleasant | 1.3 |
| Other | 7.2 |
| Nothing | 47.7 |

*/ The first eight characteristics and responses are in reference to the effects of water pollution in San Francisco Bay (126) while the remainder of the responses are in reference to user response for nine Illinois lakes.

view of the difficulties encountered in assessing intangible benefits, it does leave something to be desired when the evaluation technique is couched in terms of benefit cost analysis. Other than the above reference (62) which is concerned with the option value of Hells Canyon -- essentially a decision making model -- the review of literature has failed to uncover a single study that successfully quantifies the esthetic benefits of water quality enhancement by methods other than assigning ascribed values.

One study, the earlier referenced Dow Chemical Study (35), has ascribed various monetary values to reflect esthetic benefits of pollution abatement. For example, a value of $.25 - .50 per visitor per day was used to reflect the monetary value of sediment removal in the Potomac River estuary. Even this rather arbitrary assignment of values produces damages of $1.60 - $2.20/ton of sediment per year which produced sizable estimates of the damages of sediment to esthetically pleasing natural and man-made resources.

This actually leaves us with only two estimates of the esthetic damages of water quality degradation, one a residual method or decision making model for estimating the esthetic benefits required to equal or exceed the alternative development projects proposed for a unique natural resource (Hells Canyon Project) and the other an ascribed value for the damages of sediment to the esthetic qualities of the Potomac River and surrounding environs.

## E. SUMMARY OF WATER QUALITY MANAGEMENT AND ESTHETICS

Many have recognized that esthetic benefits of water quality enhancement may represent one of the larger sources of potential benefits of water quality enhancement. The problems associated with the quantification of these uncommensurate benefits have proven to be exceedingly complex. Other than ascribing arbitrary values to esthetic benefits or the development of elaborate decision making models to assist in evaluating development projects (references 35 and 62 respectively) the literature search has failed to uncover a single definative measure of the esthetic benefits of water quality management.

Research in this specific area falls into two broad categories. One, studies that have attempted to determine the desirable or undesirable aspects or attributes of natural resources including surface water bodies. This first group consists of the following studies that have devoted at least a portion of their emphasis to the above mentioned area of endeavor.

| Reference Number | Title/Author |
|---|---|
| 8 | Bishop, Doyle W., and Robert Aukerman, Water Quality Criteria For Selected Recreational Uses, Research Report No. 33, University of Illinois Water Resources Center, University of Illinois, Sept., 1970. |
| 83 | Munson, K. F., "Opinions of Providers and Users About Site Quality for Water-Oriented Recreation on Eight Small Lakes in Arkansas," Ph.D. Disseration, University of Illinois, Jan., 1968. |
| 126 | Willeke, G., "Effects of Water Pollution in San Francisco Bay," Ph.D. Dissertation, Stanford, University, 1969. |
| 3 | Aukerman, R., "Water Quality Criteria for Selected Recreational Uses--Site Comparisons," Thesis, University of Illinois, 1971. |
| 7 | Bevins, Malcolm I., Attitudes on Environmental Quality in Six Vermont Lakeshore Communities, Northeast Regional Research Publication, Vermont Ag. Exp. Sta., University of Vermont, Bulletin 671 June, 1972. |
| 84 | Myles, George A., "Effect of Quality Factors on Water Based Recreation in Western Nevada," Desert Res. Inst., No. 3E, Progress Report Series, Center for Water Resources Res. (Max C. Fleischmann College of Agriculture Report Series B 16), Reno, February 1970. |
| 28 | David, Elizabeth L., "Public Perceptions of Water Quality," Water Resources Res., June 1971 (3), pp. 453-57. |
| 29 | David, Elizabeth L., Richard S. Howe, and John T. Quigley, "Institutional Design for Water Quality Management: A Case Study of the Wisconsin River Basin," The Univ. of Wisconsin Water Resources Center, Tech. Report OWRR C-1228, 1970. |

The second type of study related to esthetic considerations includes those recently published works that develop and/or implement inventorial procedures and methodologies designed to quantify the uniqueness of various natural resources. Studies related to or devoting some discussion to the above area include the following:

| Reference Number | Title/Author |
|---|---|
| 86 | Nighswonger, James J., "A Methodology for Inventorying and Evaluating the Scenic Quality and Related Recreational Value of Kansas Streams," (Includes Four Selected Streams) State of Kansas, Dept. Econ. Devel., Outdoor Recreation Planning for Kansas, Report No. 32. |
| 31 | Dearinger, John A. and George M. Woolwine, "Measuring the Intangible Values of Natural Streams, Part I, Application of the Uniqueness Concept," Research Report No. 40, University of Kentucky, Water Resources Institute, Lexington, 1971. |
| 2 | Arner, D., et al., "An Ecological and Recreational Use Survey of the Luxapalila River," page 367. Water Resources Bulletin V.8, April 1972, No. 2, Permagon Press, Oxford, England. |
| 71 | Leopold, Luna B., "Landscape Esthetics," Natural History, Oct. 1969. |
| 32 | Dee, Norbert et al., "Environmental Evaluation System for Water Resource Planning," Battelle, Columbus Laboratories, January, 1972. |
| 57 | Kansas Park and Resources Authority, "An Outdoor Recreation Plan for Central Kansas - Appendix III," Kansas Planning for Development Report No. 38-III, November, 1972. |
| 66 | Krumholz, Louis A., "A Preliminary Ecological Study of Areas to be Impounded in the Salt River Basin of Kentucky," Univ. of Kentucky Water Resources Institute, Research Report No. 43, September 1971. |
| 67 | Krumholz, Louis A. and Stuart E. Neff. "A Preliminary Ecological Study of Areas to be Impounded in the Salt River Basin of Kentucky," Univ. of Kentucky, Water Resources Institute, Research Report No. 48, October, 1971. |

Although these studies may not achieve the objective of quantifying esthetic benefits in economic terms, they do successfully contribute to the requisite task of providing and implementing methods designed to ascertain (perhaps only by ranking) the relative value of natural resources. The development of uniqueness models is a logical step or activity that should be further developed or explored if the quantification of ecological benefits of water quality enhancement is to be pursued.

## SECTION IV

## WATER QUALITY AND PROPERTY VALUES

### A. INTRODUCTION

Water quality impacts on property values are again closely aligned or related to esthetic and recreational considerations. Shoreline property values surrounding lakes, reservoirs and streams are characteristically higher than the value of similarly used nonshoreline property of equal quality. This stems from several factors which surely must include water access and esthetic considerations. The intrinsically pleasing qualities of high quality water enhances the attractiveness and value of shoreline properties for seasonal or year round dwelling and possible location sites for various commercial activities.

Increasing effluent loads and the degradation of surface water bodies reduces the esthetic appreciation and the desirability of shoreline property sites. The reduction in attractiveness is conceivably reflected in declining property values. The total dollar value of all shoreline property in the U.S. again makes this beneficial use of substantial importance. The encouraging factor that is encountered in estimating property value benefits of water quality enhancement is that the market mechanism provides a possibility of assessing the property value benefits of water quality enhancement. By observing changes in the sale price of shoreline property, a model can be formulated which can include subjective or objective water quality measures to determine the effects of water quality changes. While there are many complicating factors encountered and considerable simultaneity involved, the market mechanism provides a possibility of sorting out various influences with the aid of econometric techniques.

### B. HYPOTHESIZE WATER QUALITY RELATIONSHIPS

The number of water quality constituents or characteristics that potentially influence shoreline property values are numerous, varied and perhaps need not be expanded beyond those included in Exhibits II-1 and III-1. It can again be argued that all of these pollutants are potentially important when considering property value impacts of water quality degradation. Realistically, however, the important factors would be those that are perceptable to the homeowner or site user.

Exhibit IV-1 presents the results of pollution perception studies which indicates the meaning of pollution to those interviewed. While the results of this study are couched in very vague general terms, needing some refinement, it must be recognized that public perception of pollution is not in terms of incremental units of BOD or some other pollutant but rather in the perceptible influences of pollution such as fish kills, litter, debris and similar measures.

## C. ECONOMIC ANALYSIS OF WATER QUALITY CHANGES AND PROPERTY VALUES

Several researchers have addressed the question or problem of quantifying property value impacts of surface water quality degradation. These include several that have made only passing reference to the problem and others that have faced the issue directly. These studies are listed below.

| Reference | Title/Author |
|---|---|
| 85 | Nemerow, Nelson L. and Hisashi Sumitomo, "Benefits of Water Quality Enhancement," (Onondago Lake,) Water Pollution Control Research Series, 16110 DAJ 12/70. |
| 10 | Bramer, H.C., "The Economic Aspects of the Water Pollution Abatement Program in the Ohio River Valley," Ph.D. Dissertation, University of Pittsburgh, 1960. |
| 81 | McClellan, Grant S., Protecting Our Environment, The H. W. Wilson Company, New York, 1971, Vol. 42, No. 1. |
| 27 | David, Elizabeth L., "Lakeshore Property Values: A Guide to Public Investment in Recreation," Water Resources Research, August, 1968. |
| 30 | David, Elizabeth L. and William B. Lord, "Determinants of Property Value on Artificial Lakes," Univ. of Wisconsin, Dept. of Agricultural Economics, Ag. Ec. 54, May 1969. |

Exhibit IV-1. Public perception of pollution */

| Water Quality Characteristics | Association of Specific Characteristics with Pollution by Percent Interviewed |
|---|---|
| Algae | 40 |
| Cans and Glass | 1 |
| Suds and Foam | 25 |
| Debris | 10 |
| Merky, dark | 20 |
| Weeds | 3 |

*/ Results of pollution perception study in selected Wisconsin study area (29).

The first two (10 and 81) can be quickly summarized. Bramer (10) was concerned with the benefits of pollution abatement in the Ohio River Valley and included a brief section on property value benefits. The procedures employed were quite crude and must be further refined. The approach that was utilized in this study assumes that inauguration of secondary treatment everywhere would enhance the value of shoreline property by 10 percent which was assumed to be one percent of the total land area in the geographical area under consideration. This obviously can be accepted only in the absence of more sophisticated methods.

Reference 81 is not a study of property values per se but instead simply makes reference to a documented damage that is interesting and intriguing. Reference is made to the effects of increased salinity in Hudspeth County, Texas which is purported to be the cause of agricultural land values declining from $1,000 per acre to $50 per acre. Such a drastic decline must be viewed as an extreme example and atypical of the effects of salinity on agricultural land values.

The latter group (references 85, 27 and 30) consists of those studies that have devoted more than just passing reference to the property value affects of increased water quality degradation.

The procedure utilized in the Onondago Lake study (85) was essentially a procedure which compared the value of shoreline property for various reservoirs with different water quality. The differences in property values of similarly used property was attributed to water quality differences. The total difference was prorated over a five year period to reflect the annual property value benefits of water quality enhancement. As previously encountered, the property value changes were not well specified. Many influences -- distance from reservoirs, value of improvements, access, variations in seasonal as opposed to year around dwellings and general land uses -- should be refined or further explored to increase the acceptability of the resulting estimates.

The other studies (27 and 30), both by the same author, have utilized multiple regression methods to explain variation in property values. A water quality variable was included in the model and was found to explain four percent of the variations in property values in the study area. These studies formulate several regression models with several independent variables to explain variation in property values as influenced by water quality. While the study includes only subjective measures of pollution, the model developed and utilized is preferred to any of the above previously mentioned property value studies.

## D. SUMMARY OF PROPERTY VALUE BENEFITS AND WATER QUALITY ENHANCEMENT

There is reason to be encouraged with the progress that has been made in assessing property value benefits of water quality enhancement. This encouragement stems from the fact that the market mechanism affords an opportunity to model and estimate the economic benefits of water quality degradation or water quality enhancement by econometric analysis of observed property value changes.

The second source of encouragement stems from the fact that several researchers have developed and implemented regional property value models. While there may be significant aggregation problems the format for regional property value models is reasonably well established. In this regard it is also encouraging to note that a national property value study has been recently completed for EPA. This study is entitled, "Benefits of Water Pollution Control on Property Values," and was sponsored by the office of Research and Monitoring.

## SECTION V

## ECOLOGY AND WATER QUALITY

### A. INTRODUCTION

The amount of literature that has been published in reference to ecology and water quality is voluminous. This includes discussions on nearly every conceivable facet of water quality management related to ecology. This includes esoteric discussions of the impacts of water quality degradation on a large variety of terrestrial or aquatic life. Specific impacts such as DDT concentrations in wildlife, destruction of kelp growth or the interruption of the feeding and spawning habits of aquatic life are representative examples.

Even when couched in terms of damages or potential damages by specific pollutants, the documentation is virtually endless. Much of the work is formulated in a very esoteric manner which has emanated from numerous controlled environmental simulations or bioassay procedures conducted by various researchers.

It is beyond the scope or level of effort of this report to include a comprehensive listing of references dealing with ecology and water quality management. We will therefore deviate from the previously adopted format and present only a general discussion of the state of the arts assessment of estimating ecological benefits of water quality enhancement.

### B. GENERAL SUMMARY

A representative sampling of literature relevant to ecology and water quality management was reviewed by DPRA staff members. This includes numerous previously cited references which are directly or indirectly concerned with various ecological aspects of water quality degradation. The results of this review are presented below in a very brief, verbal summary.

A sizable portion of the literature concerned with ecology and water quality degradation is focused on presenting the undesirable effects of specific pollutants on various species of fish. This includes the undesirable effects of toxic substances, thermo pollution, sedimentation and numerous other pollutants on a wide variety of species. Since the

tolerance level varies by species, life cycle, season of the year, and numerous other water quality conditions, there is an endless number of specific effects or combinations of specific pollutants that can be discussed. A cursory review of the bibliography reveals the diversity of topics considered.

The objective of presenting documentation of hypothesized or potential ecological damages by specific pollutant would be unobstructed if time permitted. An excellent example of two very comprehensive studies is reference 37 and 38. These studies summarize the effect of a large number of pesticides and chemical compounds on a variety of nontarget species. These two sources contain data on the ecological effects of hundreds of pesticides and chemical compounds and hundreds of nontarget species.

Not all of the references are as comprehensive in their coverage or as esoteric in their presentation. For example, reference 41 contains data of fish kills in the U.S. in 1971. The number of kills, source of pollution and location is covered in this EPA publication.

The rhetorical question that is again encountered is, "What has been done to quantify these ecological damages in economic terms." While only limited time was available to explore the work that has been done concerning the economics of ecological damages or benefits, the knowledge, experience and results derived in seeking estimates of other intangible or incommensurate benefits of water quality management are believed to be equally appropriate for the state of the arts summary concerning the economic quantification of ecological benefits of water quality enhancement. That is, while there has been a great deal said and done in reference to ecological benefits of water quality enhancement, very little (virtually nothing) has been accomplished in the area of expressing these damages in economic terms.

While it is understandable that this specific area has not been comprehensively studied by the economist, there is a conspicuous absence of even the inclination to undertake such an endeavor. There is very little evidence that a significant amount of effort has been devoted to initiating work on quantifying the economic impacts of ecological changes associated with environmental degradation. Of all the areas discussed as of this point, this specific area is the most neglected. The general articles addressing this problem are filled with terms such as incommensurate, immeasurable, inseparable or other equally vague phrases. As of this time, these descriptions are most appropriate.

## SECTION VI

## OTHER BENEFICIAL USES AND GENERAL SUMMARY

### A. OTHER BENEFICIAL USES

The beneficial uses that have not as of this time even entered the discussion include human health and the entire area of production, (i.e., beneficial use categories III and IV respectively). We are not, as of this time, prepared to submit a complete discussion of these areas but the exposure has been sufficiently great to extend a few summary comments.

#### Health

There are a great many unknowns encountered when discussing water quality associated health impacts. The widespread utilization of pre-use chlorination has eliminated many adverse water quality associated health impacts. Notwithstanding, there is considerable evidence that water quality degradation is responsible for a variety of human health disorders and associated effects.

References 22, 26, 77, and 128 are representative of much of the work that has been done in the area. Again the work tends to be highly esoteric discussing very specific health impacts associated with specific pollutants. The task of estimating the national economic impacts relating to adverse health effects of water quality degradation has not, as of this time, been undertaken. This endeavor will again be hampered by problems associated with evaluating intangible, nonmonetary considerations such as the value of pain, suffering or the loss of human life. When all factors have adequately been accounted for, i.e., loss of life, work days lost, reduced productivity and other costs such as that expended for medication and professional health care; the total benefits and/or damages may be rather substantial. It is also likely that the fear of health impacts or the epidemic risks associated with deteriorating water quality may be sufficiently great to justify restrictive water quality standards. These considerations, including risk, must be properly accounted for when estimating water quality associated health impacts.

#### Production

The other broad area and as of this point untouched, is beneficial use IV, i.e., production. While no one has estimated national production

benefits of water quality enhancement, there are fewer methodological problems encountered in that the procedure will possibly involve estimating of additional costs associated with physical damages or the cost of damage prevention.

Very little time was spent searching for publications relevant to the production area. The work that has surfaced which deserves special mention includes the following articles or publications.

Researchers concentrating on the production area should devote special attention to reference 82 which is one of the most comprehensive empirical studies of the cost of water quality degradation to residential and nonresidential water users. Reference 74 is of interest to these estimating the industrial costs of thermo pollution. In addition there are several other presently unpublished studies by EPA staff members which represent the best current single source of information concerning the economics of water quality degradation and domestic water usage and commercial fishing. Both of these studies were undertaken and completed by Dr. Dennis Thansky, Office of Research and Monitoring, U.S. Environmental Protection Agency.

The economic quantification or assessment of the production benefits of water quality enhancement has not at this time been completed, even though much of the data is available and the methodological problems are relatively iew.

## B. GENERAL SUMMARY

The major impetus for this report emanates from the construction and presentation of a benefit matrix (Exhibit A-15) in Phase II Research Needs and Priorities: Pollution Control Benefits and Costs with Emphasis on Water, by DPRA. This benefit matrix is presented below as Exhibit VI-1.

The documentation of the use-quality relationships presented in this matrix (indicated by a 1D notation) was somewhat subjective and alsc utilized established state and/or federal water quality criteria that have been known to be rather insensitive of actual use-quality relationships. It was therefore decided that a subsequent literature search would be advisable to further document specific use-quality relationships and to present a brief state of the arts summary. A brief summary of the current state of the arts (with emphasis on estimating water quality associated benefits) is presented below.

Exhibit VI-1. State-of-the-arts of pollution-beneficial use potential relationships, over all ranges of water quality

| | HEALTH | PRODUCTION | | | | | | | | | | | | | | | ESTHETICS | | | | ECOLOGICAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Industrial | | | | | | | | | | | | | | | | Recreation | | | |
| | Human Health | Mun. Preuse Treatment | Domestic Uses | Ag. Irrigation | Commercial Fishing | Power Generation | Navigation | (20) Food and Kindred Prod. | (22) Textile Mill Products | (24) Lumber and Wood Prod. | (26) Paper and Allied Prod. | (28) Chem. and Allied Prod. | (29) Petroleum & Coal Prod. | (30) Rubber and Plastics | (31) Leather | (32) Stone, Clay and Glass | (33) Primary Metals | Esthetic Enjoyment | Non-contact | Contact | Property Values | |
| BOD | 0U | 1D | 0U | 1D | 1D | 1D | 1U | 1D | 0D | 0U | 0U | 0D | 0U | 0D | 0U | 0D | 1D | 1D | 1D | 1D | 1D | 1D |
| COD | 0U | 1D | 0U | 1D | 1D | 1D | 1U | 1D | 0D | 0U | 0U | 0D | 0U | 0D | 0U | 0D | 1D | 1D | 1D | 1D | 1U | 1D |
| pH | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 0D | 1D | 1D | 1U | 1U |
| Coliform | 1D | 1D | 0U | 1D | 1D | 0U | 0U | 1D | 0U | 0U | 0U | 0U | 0U | 0U | 1D | 0D | 0U | 1D | 1D | 1D | 1U | 1D |
| Nitrogen | 1D | 1D | 0U | 1D | 1D | 0D | 1U | 1D | 0U | 0U | 0D | 1D | 0D | 0D | 0U | 0U | 0U | 1U | 1D | 1D | 1D | 1D |
| Phosphate | 0U | 1D | 0U | 0U | 1D | 0U | 1U | 1D | 0U | 0U | 0U | 1U | 0U | 0U | 0U | 0U | 0U | 1D | 1D | 1D | 1D | 1D |
| Toxic Sub.*/ | 1D | 1D | 1D | 1D | 1D | 0U | 0U | 1D | 1U | 0U | 1D | 1U | 1U | 1U | 1D | 1U | 1U | 0D | 1D | 1D | 1U | 1D |
| Hardness | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 0U | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 0D | 0D | 0U | 0U | 1D |
| TDS | 1D | 1D | 1D | 1D | 1D | 1D | 1U | 1D | 1D | 1U | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 0D | 1U | 1U | 1U | 1D |
| TSS** | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1U | 1D | 1D | 1D | 1D | 1D | 1U | 1D |
| Temperature | 0U | 0U | 1D | 1D | 1D | 0D | 0U | 0D | 1U | 0U | 1D | 0D | 1U | 0U | 0U | 0U | 1U | 0D | 1D | 1D | 1U | 1D |
| Oil | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 1D | 0U | 1D | 1D | 0U | 1U | 1U | 1U | 1D | 1D | 1D | 1D | 1U | 1D |
| Color | 0U | 1D | 1D | 0U | 1D | 1D | 0U | 1D | 1D | 1D | 1D | 1D | 0D | 1D | 1D | 0D | 0U | 1D | 1D | 1D | 1U | 1U |
| Turbidity | 1D | 1D | 1D | 0U | 1D | 1D | 0U | 1D | 1D | 1D | 1D | 1U | 1D | 1D | 1D | 0U | 0U | 1D | 1D | 1D | 1D | 1D |
| Odor | 0D | 1D | 0U | 0U | 1D | 0D | 0U | 1D | 0D | 0U | 0U | 0D | 0U | 0D | 0U | 0U | 0U | 1D | 1D | 1D | 1D | 1U |
| Taste | 0D | 1D | 0U | 0U | 1D | 0U | 0U | 1D | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 0D | 1D | 0U | 1U |
| Radionucles | 1D | 1D | 0U | 1D | 1D | 0U | 0U | 1D | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 0U | 1D | 1D | 1D | 1U | 1D |
| Floating Solids | 0U | 1D | 1U | 0D | 1D | 0U | 1D | 1D | 1U | 1U | 1U | 1U | 1U | 1U | 1U | 1U | 1U | 1D | 1D | 1D | 1D | 1U |

*/ Includes heavy metals.

**/ Includes settable solids.

1 => pollutant has an effect upon usability
0 => pollutant has no effect upon usability within water quality ranges normally encountered
D => a pollutant-use relationship has been documented
U => documentation of a pollutant-use relationship (or lack of one) has not been found, but such a relationship (or lack of one) seems plausible


References:
1. "Water Quality Criteria," FWPCA, 1968.
2. Todd, "The Water Encyclopedia," 1970.
3. "Manual on Industrial Water and Industrial Waste Water,", ASTM Special Technical Publication No. 148-I, 1966.
4. Zajic, J. I., "Water Pollution--Disposal and Reuse," 1971.
5. Lund, H. F., "Industrial Pollution Control Handbook," 1971.
6. "Cleaning our Environment the Chemical Basis for Action," Am. Chem. Soc. 1969.

The literature review indicates that virtually every use-quality relationship denoted by a 1D presented in the initial benefit matrix could be further supported by several references. This could be accomplished without utilizing established and arbitrary state or federal water quality criteria. It is also quite likely that several of the use-quality relationships initially presented as having no effect on usability, i.e., denoted by the notation OD, could be changed to the former notation indicating that the pollutant has a potential effect on usability.

If, however, the criteria is to present a summary of the economic studies that have quantified such use-quality relationships, it is quickly discovered that there are many use-quality relationships that have not been explored by the economist. While the economic relationships have not been adequately explored at this time, there are many studies that are potentially useful. Some of the relevant references for the beneficial uses discussed are presented below in Exhibit **VI-2.** As indicated in this exhibit, there is a conspicuous absence of references concerned with the economics of ecological damages of water quality degradation. Two beneficial uses, i.e., health and production, were not included in the above summary table. These have been briefly summarized in the text. While there is a great disparity in the value of the above cited references, there is something to be gained from all.

The following conclusions are also presented at this time.

Recreational Benefits of Water Quality Enhancement

While many methodological questions are, as of this time unanswered, there are indications that this single area is where much of the future research time and money should be focused. This particular water use is perhaps the largest single source of benefits of water quality enhancement. Research efforts should be devoted to estimating national recreational benefits of pollution abatement.

Property Value Benefits of Water Quality Enhancement

The methodology and estimates of property value benefits should be reasonably well in hand in the immediate future and should not be the subject of additional emphasis until some of the other deficient areas have been satisfied.

Exhibit VI-2. Selected References Concerned with Economies of Water Quality Management Use Avoidance, Perception or Value of Natural Resources by Beneficial Use

| Beneficial Use/Reference | | Specific Use or Topic | Pollutant or Emphasis |
|---|---|---|---|
| Recreation | | | |
| | 85 | General Recreation | Pollution Index |
| | 115 | Sport Fishing | Kraft mill effluents |
| | 64 | General Recreation | DO |
| | 10 | General Recreation | BOD |
| | 79 | General Recreation | BOD |
| | 35 | General Recreation | Sedimentation |
| | 99 | General Recreation | Algae and Beach Improvement and temperature |
| | 59 | Sport Fishing | pH |
| Esthetics | | | |
| | 35 | General Esthetics | Sedimentation |
| | 62 | General Esthetics | Resource Development |
| | 8, 83, 126 | Use avoidance, public | General undesirable con- |
| | 3, 7, 84, | perception and/or | stituents |
| | 28, 29 | desirable qualities | |
| | 86, 31, 2, | Methodology or inven- | Ascertaining unique attri- |
| | 71, 32, 57 | torial procedures | butes and/or desirable or |
| | 66, 67 | | undesirable qualities |
| Property Values | | | |
| | 85, 10, 81 | Methodology and/or | BOD, perceptible water |
| | 27, 30 | empirical estimate of property value benefits | quality characteristics or subjective measures of pollution |
| Ecological | | | |
| | -- | -- | -- |

## Esthetic Benefits of Water Quality Enhancement

Estimating the esthetic benefits emanating from pollution abatement is somewhat less refined or developed than estimating recreational benefits. The recent emphasis on methodology designed to evaluate the uniquenesses of natural resources offers some encouragement but, in all likelyhood, progress in this area will be only nominal for some time.

## Ecological Benefits of Water Quality Enhancement

Little has been done in this country to quantify the ecological benefits of water quality enhancement in economic terms. While this area may be the source of sizable benefit estimates, the lack of background work probably prevents immediate returns on time invested. It is our understanding, however, that several studies in other countries have been recently completed.

Researchers estimating the health benefits of water quality enhancement will without a doubt also encounter difficult methodological problems. While this area may be the source of sizable benefits, they are viewed as small relative to other water uses.

The entire area of estimating the production benefits of water quality enhancement will be less difficult (relative to the above mentioned areas). The data and methodology is reasonably well in hand to initiate such an endeavor. Notwithstanding, it will be a time consuming and laborious task.

For the above, as well as other reasons, it is believed that the following list indicates the relative priorities that should be attached to estimating the benefits of water quality management.

1. Recreation
2. Esthetics
3. Ecological
4. Production
5. Health
6. Property values

Considerable insight into the progress and accomplishments of the economist in estimating the benefits of water quality enhancement is provided by the following material.

"From the replies of 36 States to a questionnaire seeking data on which to base an estimate of the economic and social effects of the destruction of fish, water-fowl, and other wild life by pollution, it is evident that available data permit only general conclusions. Reasonably comprehensive and accurate surveys of this group of problems are generally lacking in this country. Such studies are essential before any close evaluation of the large economic losses in this field is possible. An extension of such studies as those made on the upper Mississippi River jointly by the State Boards of Health of Minnesota and Wisconsin would be very helpful. In that study, for example, it was reported that the annual loss to commercial fishing and clamming is $95,000; the annual damage to sport fishing and attendant industries $35,000; while decreased property value in the Twin Cities was estimated at $2,000,000 and damage to lands for recreational purposes at $1,500,000.

Other states, such as Indiana, Iowa and Virginia, have made efforts to evaluate similar economic losses which they believe would aggregate millions of dollars annually. Most of the states report acute situations in restricted localities.

Without doubt an extended study of the many published reports on the subject and a thorough analysis of records in possession of the State Conservation Departments and Fish and Game Commissions would be revealing. As a rule, however, the relevant data are so scattered, so incomplete, and, because of the intangible nature of some of the losses so inconclusive, that it is impossible at present to state any figure as representing the national economic burden of pollution." (108)

It is interesting and indeed disappointing to note that the basic problems mentioned above, i.e., quantification of intangible losses and the difficulties associated with estimating national pollution losses are still the basic problems encountered today. This takes on even greater meaning when it is realized that the above excerpt was taken from an article published in 1935.

## SECTION VII

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(See Addendum, page 82 for additional references.)

## SECTION VII

## APPENDICES

Two brief appendices have been included in this section. The first is concerned with further documentation of recreational and ecological damages and the second is concerned with undesirable human and natural environmental qualities.

### A. Appendix A -- Damage Documentation

Appendix A includes additional documentation of water quality associated damages and critical damage levels or thresholds. These are primarily related to recreational and esthetic water quality consideration but also includes selected production damages such as reduced commercial fish catches. These damages are also cross referenced in Exhibit II-2 in the text and identified separately as attachments.

ATTACHMENT A - Reference 76

Lund, Herbert F., Industrial Pollution Control Handbook, McGraw-Hill Book Company.

**Maximum Recommended Temperatures for Development of Various Fishes**

| Max temp, °F | Spawning and/or egg development | Growth |
|---|---|---|
| 48 | Lake trout, walleye, northern pike, Atlantic salmon | |
| 55 | Salmon, trout | |
| 68 | Perch, smallmouth bass | Salmon, trout |
| 75 | Largemouth and other bass | |
| 80 | Catfish, shad | |
| 84 | ..... | Pike, perch, smallmouth bass, walleye |
| 90 | ..... | Largemouth bass, bluegill, crappie |
| 93 | ..... | Catfish, gar, other bass, shad |

ATTACHMENT B - Reference 33

Detwyler, Thomas R., Man's Impact on Environment, University of Michigan, McGraw-Hill Book Co., 1971

**Catch of major species and total commercial catch (thousands of pounds) per year in Lake Michigan for various periods.**

| Period | Native species | | | | | | New species | | | Total major species | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lake trout | Lake herring | Suckers | Whitefish | Chubs | Yellow perch | Carp[a] | Smelt[b] | Alewife[c] | Pounds | Percentage of total catch | Other species | Total catch |
| 1898–1909 | 7,225 | 16,977 | 1,810 | 2,715 | 2,061 | 3,866 | 261 | – | – | 34,915 | – | – [d] | 35,149 |
| 1910–1919 | 6,763 | 8,642 | 4,035 | 1,670 | 3,525 | 2,411 | 247 | – | – | 27,293 | – | – [d] | 27,059 |
| 1920–1929 | 7,001 | 4,015 | 2,117 | 2,111 | 2,902 | 1,537 | 679 | – | – | 20,362 | – | – [d] | 20,477 |
| 1930–1934 | 5,342 | 4,985 | 2,258 | 3,730 | 4,387 | 1,199 | 769 | 425 | – | 23,075 | 98.0 | 465 | 23,540 |
| 1935–1939 | 5,038 | 4,621 | 2,280 | 1,201 | 5,295 | 2,406 | 1,605 | 1,462 | – | 23,908 | 98.7 | 312 | 24,220 |
| 1940–1944 | 6,579 | 1,830 | 2,125 | 1,351 | 1,971 | 2,729 | 1,702 | 2,913 | – | 21,200 | 97.8 | 474 | 21,674 |
| 1945–1949 | 2,675 | 6,044 | 1,901 | 3,756 | 5,435 | 1,446 | 1,319 | 765 | – | 23,324 | 95.6 | 1,066 | 24,407 |
| 1950–1954 | 14 | 8,000 | 882 | 1,436 | 10,482 | 1,963 | 1,170 | 4,384 | – | 28,334 | 97.1 | 848 | 29,182 |
| 1955–1959 | <1 | 3,639 | 652 | 105 | 9,947 | 3,055 | 1,785 | 6,983 | 568 | 26,735 | 97.8 | 592 | 27,327 |
| 1960 | <1 | 233 | 767 | 124 | 12,695 | 3,285 | 1,416 | 3,267 | 2,370 | 24,158 | 99.4 | 153 | 24,311 |
| 1961 | <1 | 177 | 494 | 412 | 12,133 | 4,959 | 1,842 | 2,152 | 3,199 | 25,370 | 99.3 | 189 | 25,559 |
| 1962 | <1 | 116 | 263 | 278 | 11,115 | 4,050 | 1,206 | 1,546 | 4,742 | 23,317 | 99.3 | 158 | 23,475 |
| 1963 | <1 | 41 | 299 | 298 | 7,460 | 4,872 | 1,277 | 1,203 | 5,396 | 20,795 | 98.9 | 226 | 21,021 |
| 1964 | <1 | 34 | 215 | 788 | 5,172 | 5,835 | 1,320 | 969 | 11,744 | 26,080 | 99.5 | 121 | 26,201 |
| 1965 | <1 | 47 | 168 | 995 | 7,441 | 1,297 | 2,016 | 927 | 14,007 | 26,900 | 99.7 | 94 | 26,994 |
| 1966 | <1 | 49 | 402 | 1,422 | 7,228 | 654 | 2,713 | 1,110 | 29,002 | 42,580 | 99.8 | 97 | 42,677 |

[a] Introduced in the late 1800's.
[b] Introduced into Crystal Lake tributary to Lake Michigan in 1912.
[c] Invaded the upper Great Lakes via the Welland Canal and was first reported in Lake Michigan in 1949.
[d] Data incomplete.

## ATTACHMENT B (continued)

**Production of lake trout, chubs, and alewives, and estimated pounds of fish destroyed by spawning run sea lampreys in Lake Michigan in 1935–66.**

| Year | Lake trout | Chubs | | | Alewife | Fish destroyed by sea lamprey[a] |
|---|---|---|---|---|---|---|
| | | Gillnet | Trawl | Total | | |
| | | *(Thousands of pounds of fish)* | | | | |
| 1935 | 4,873 | 5,794 | – | 5,794 | – | – |
| 1936 | 4,763 | 5,674 | – | 5,674 | – | – |
| 1937 | 4,988 | 5,579 | – | 5,579 | – | – |
| 1938 | 4,906 | 5,404 | – | 5,404 | – | – |
| 1939 | 5,660 | 4,025 | – | 4,025 | – | – |
| 1940 | 6,266 | 1,648 | – | 1,648 | – | – |
| 1941 | 6,787 | 1,630 | – | 1,630 | – | – |
| 1942 | 6,484 | 1,755 | – | 1,755 | – | – |
| 1943 | 6,860 | 2,214 | – | 2,214 | – | – |
| 1944 | 6,498 | 2,607 | – | 2,607 | – | – |
| 1945 | 5,437 | 4,221 | – | 4,221 | – | – |
| 1946 | 3,974 | 4,525 | – | 4,525 | – | 116 |
| 1947 | 2,425 | 5,087 | – | 5,087 | – | 554 |
| 1948 | 1,197 | 5,929 | – | 5,929 | – | 919 |
| 1949 | 342 | 7,421 | – | 7,421 | – | 1,467 |
| 1950 | 54 | 9,291 | – | 9,291 | – | 5,046 |
| 1951 | 11 | 10,301 | – | 10,301 | – | 11,744 |
| 1952 | 4 | 11,098 | – | 11,098 | – | 3,068 |
| 1953 | [b] | 11,151 | – | 11,151 | – | 8,591 |
| 1954 | [b] | 10,568 | – | 10,568 | – | 6,762 |
| 1955 | [b] | 10,895 | – | 10,895 | – | 5,576 |
| 1956 | 0 | 10,913 | – | 10,913 | [b] | 5,275 |
| 1957 | 0 | 10,546 | – | 10,546 | 220 | 5,622 |
| 1958 | 0 | 9,583 | – | 9,583 | 1,357 | 2,711 |
| 1959 | [b] | 6,392 | 1,404 | 7,796 | 1,264 | 2,313 |
| 1960 | [b] | 5,530 | 7,129 | 12,695 | 2,370 | 1,782 |
| 1961 | [b] | 5,915 | 6,218 | 12,133 | 3,199 | 3,452 |
| 1962 | [b] | 6,346 | 4,769 | 11,115 | 4,742 | 2,167 |
| 1963 | 26 | 4,050 | 3,410 | 7,460 | 5,396 | 1,999 |
| 1964 | [b] | 3,381 | 1,791 | 5,172 | 11,744 | 1,230 |
| 1965 | [b] | 6,857 | 583 | 7,440 | 14,007 | 877 |
| 1966 | [b] | 6,990 | 238 | 7,228 | 29,002 | 313 |

[a] Based upon a proportional expansion of the abundance index (Table 44.2) to reflect the sea lamprey count in 1958 when the maximum number of streams were blocked with counting barriers (Great Lakes Fishery Commission, 1958) which was doubled on the assumption that one-half of the spawning streams were blocked, and that each lamprey killed 37 lb of fish to reach maturity (Packer and Lennon, 1956).

[b] Less than 500 lb. Most lake trout caught since 1953 were hatchery-reared fish planted to measure survival and planting techniques.

ATTACHMENT C - Reference 107

Spaulding, Willard M., Jr. and Ronald D. Ogden, "Effects of Surface Mining on the Fish and Wildlife Resources of the United States," Bureau of Sport Fisheries and Wildlife, U.S. Dept. of the Interior, Aug. 28, 1968.

***Estimated annual fishing and hunting benefits from reclamation of surface-mined areas, by census regions***

[Values calculated from average present-day fishing and hunting use figures evaluated on basis of the Interim Schedule of Values issued May 24, 1960, and Supplement 1, Evaluation Standards for Primary Outdoor Recreation Benefits, Ad Hoc Water Resources Council, June 4, 1964]

| Census region | Present use | | Use with basic reclamation | | Use with full development | |
|---|---|---|---|---|---|---|
| | Man-days | Value | Man-days | Value | Man-days | Value |
| New England | 82, 500 | $186, 000 | 302, 500 | $712, 000 | 601, 500 | $1, 365, 000 |
| Middle Atlantic | 55, 600 | 157, 000 | 2, 218, 600 | 6, 329, 000 | 9, 882, 600 | 23, 873, 000 |
| South Atlantic | 180, 600 | 325, 000 | 2, 686, 600 | 4, 253, 000 | 6, 828, 600 | 9, 932, 000 |
| East North Central | 297, 200 | 733, 000 | 1, 842, 200 | 4, 097, 000 | 4, 767, 200 | 9, 799, 000 |
| East South Central | 327, 200 | 425, 000 | 3, 723, 200 | 4, 501, 000 | 7, 069, 200 | 8, 474, 000 |
| West North Central | 1, 204, 500 | 2, 165, 000 | 5, 410, 500 | 9, 417, 000 | 7, 111, 500 | 12, 089, 000 |
| West South Central | 5, 183, 000 | 5, 309, 000 | 22, 521, 000 | 24, 296, 000 | 27, 157, 000 | 30, 901, 000 |
| Mountain | 110, 800 | 292, 000 | 959, 800 | 2, 731, 000 | 3, 111, 800 | 7, 791, 000 |
| Pacific | 67, 900 | 201, 000 | 504, 900 | 1, 503, 000 | 1, 833, 900 | 4, 572, 000 |
| Total | 7, 509, 300 | 9, 793, 000 | 40, 169, 300 | 57, 839, 000 | 68, 363, 300 | 108, 796, 000 |

ATTACHEMENT D - Reference 16

Ciccio, Leonard L., Water and Water Pollution Handbook, Marcel Dekker, Inc., New York, Vols. I, II, III, IV, 1973.

Threshold Concentrations of Various Substances that Taint Fish Flesh[a]

| Compound | Concentration, mg/liter |
|---|---|
| *p*-Quinone | 0.5 |
| *p*-Toluidine | 20.0 |
| Pyridine | 5.0 |
| Quinoline | 0.5–0.1 |
| Naphthalene | 1.0 |
| α-Naphthol | 0.5 |
| β-Naphthol | 1.0 |
| α-Naphthylamine | 3.0 |
| Xylenol | 1.0–5.0 |
| Pyrocatechol | 2.5 |
| Resorcinol | 30.0 |
| Pyrogallol | 20.0–30.0 |
| Phloroglucinol | 10.0 |

[a]From Ref. 68, by courtesy of Academic Verlag, Berlin

ATTACHMENT E - Reference 61

Klein, L., River Pollution, Vol 2: Cures and Effects, Butterworth, London, 1962, 456 pp.

Concentrations of phenols and other organic compounds present in coal carbonization effluents having adverse effects on taste of fish

| *Compound* | *Fish tested* | *Toxicity to fish (threshold value)* p.p.m. | *Approximate concentration (threshold value) at which fish flesh is tainted* p.p.m. |
|---|---|---|---|
| Phenol | trout, carp | 9·5 | 25 |
| Cresols | trout, carp | 10–15 | 10 |
| Coke oven wastes | freshwater fish | 3–5 | 0·02–0·1 |
| Phenols in polluted river | minnows | 0·08 | 0·02–0·15 |
| 1:3:4-xylenol | carp | 10 | 5 |
| 1:3:5-xylenol | rudd | 18 | 1 |
| 1:2:4-xylenol | rudd | 5 | 1 |
| Pyrocatechol | carp | 15 | 2·5 |
| Resorcinol | carp | 35 | 20 |
| *p*-toluidine | rudd | 50 | 20 |
| Pyridine | carp, rudd | 160–200 | 5 |
| Quinoline | carp | 10 | 0·5–1 |
| Naphthalene | rudd | — | 1 |
| α-naphthol | rudd | 2 | 0·5 |
| β-naphthol | carp, rudd | 2 | 1 |
| α-naphthylamine | rudd | 6 | 3 |

ATTACHMENT F - Reference 115

Stoevener, Herbert H., et al., Multi-Disciplinary Study of Water Quality Relationships: A Case Study of Yaquina Bay, Oregon, Oregon State University, Special Report 348, Feb., 1972.

Percent Survival of Species in Various Concentrations of KME, and Median Tolerance Limits of KME for Each Species

| Species | Time (hrs) | Percent Concentration of KME | | | | | | $TL_m$ (% KME) | Control |
|---|---|---|---|---|---|---|---|---|---|
| | | 6.0 | 9.4 | 14.0 | 21.0 | 32.0 | | | |
| White Seaperch | 48 | 94 | 100 | 61 | 39 | 0 | | 17.0 | 100 |
| (N = 18) | 96 | 83 | 72 | 0 | 0 | 0 | | 10.6 | 100 |
| | | 4.0 | 6.0 | 9.0 | 13.0 | 20.0 | | | |
| Striped Seaperch | 48 | 100 | 90 | 90 | 100 | 20 | | 17.3 | 100 |
| (N = 10) | 96 | 100 | 80 | 60 | 0 | 0 | | 9.6 | 80 |
| | | 5.0 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | | |
| Starry Flounder | 48 | 100 | 94 | 72 | 30 | 0 | 0 | 25.0 | 94 |
| (N = 18) | 96 | 94 | 67 | 6 | 0 | 0 | 0 | 12.2 | 94 |
| | | 5.0 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | | |
| English Sole | 48 | 100 | 95 | 45 | 0 | 0 | 0 | 18.7 | 100 |
| (N = 20) | 96 | 100 | 35 | 0 | 0 | 0 | 0 | 8.5 | 100 |
| | | 8.0 | 12.0 | 17.0 | 24.0 | 35.0 | | | |
| Kelp Greenling | 48 | 80 | 90 | 80 | 70 | 40 | | 31.0 | 100 |
| (N = 10) | 96 | 80 | 70 | 40 | 0 | 0 | | 15.2 | 100 |
| | | | | | 30.0 | 40.0 | 50.0 | | |
| Dungeness Crabs | 48 | | | | 100 | 100 | 100 | -- | 88 |
| (N = 17 small) | 96 | | | | 100 | 100 | 94 | -- | 82 |

ATTACHMENT G - Reference 61

Klein, L., River Pollution, Vol. 2: Cures and Effects, Butterworth, London, 1962, 456 pp.



Toxicity to fish of some common inorganic gases in aqueous solution

| *Gas* | *Formula* | *Approximate toxic concentration to fish* p.p.m. |
|---|---|---|
| Hydrogen sulphide (sulphuretted hydrogen)* | $H_2S$ | 0·5–1·0 |
| Chlorine† | $Cl_2$ | 0·05–0·2 |
| Ozone | $O_3$ | 0·1–1·0 |
| Phosphine | $PH_3$ | about 3·6 |

ATTACHMENT H - Reference 61

Klein, L., River Pollution, Vol 2: Cures and Effects, Butterworth, London, 1962, 456 pp.

Concentrations of phenols and other organic compounds present in coal carbonization effluents having adverse effects on taste of fish

| *Compound* | *Fish tested* | *Toxicity to fish (threshold value)* p.p.m. | *Approximate concentration (threshold value) at which fish flesh is tainted* p.p.m. |
|---|---|---|---|
| Phenol | trout, carp | 9·5 | 25 |
| Cresols | trout, carp | 10–15 | 10 |
| Coke oven wastes | freshwater fish | 3–5 | 0·02–0·1 |
| Phenols in polluted river | minnows | 0·08 | 0·02–0·15 |
| 1:3:4-xylenol | carp | 10 | 5 |
| 1:3:5-xylenol | rudd | 18 | 1 |
| 1:2:4-xylenol | rudd | 5 | 1 |
| Pyrocatechol | carp | 15 | 2·5 |
| Resorcinol | carp | 35 | 30 |
| *p*-toluidine | rudd | 50 | 20 |
| Pyridine | carp, rudd | 160–200 | 5 |
| Quinoline | carp | 10 | 0·5–1 |
| Naphthalene | rudd | — | 1 |
| α-naphthol | rudd | 2 | 0·5 |
| β-naphthol | carp, rudd | 2 | 1 |
| α-naphthylamine | rudd | 6 | 3 |

ATTACHMENT I - Reference 61

Klein, L., River Pollution, Vol. 2: Cures and Effects, Butterworth, London, 1962, 456 pp.

Relation between thickness of oil film on water, appearance and amount of oil present[17]

| *Approximate thickness of oil film* (decimals of an inch) | *Appearance of oil on surface of water* | *Approximate amount of oil for film 1 sq. mile in area* (Imperial gallons) |
|---|---|---|
| 0·0000015 | Barely visible | 21 |
| 0·0000030 | Visible as silvery sheen | 42 |
| 0·0000060 | First traces of colour | 83 |
| 0·0000120 | Bright bands of colour | 167 |
| 0·0000400 | Colours begin to turn dull | 555 |
| 0·0000800 | Colours much darker | 1,110 |

## B. Appendix B -- Undesirable Esthetic Qualities

Appendix B includes a variety of esthetic considerations that have been shown to be undesirable by recreational and nonrecreational users. This list contains many factors that are not directly related to water quality but have been shown to be important esthetic considerations in references

## SELECTED UNDESIRABLE ESTHETIC QUALITIES

Water clarity in swimming area
Algae, weeds, and plant growth
Litter and trash in water
Cleanliness compared with past years
Quality of lake for recreation
Fishing compared with past years

Odors evident from burning garbage or trash
Odors evident from improper handling of sewage
Community cleanliness: evidence of litter and trash
Evidence of sewage disposal problem
Evidence of trash disposal problem

General community attractiveness
Attractiveness of homes
Quality of home construction
Maintenance level of homes
Landscaping between homes
Layout of streets and lots
Size of home lots
Spacing between homes
Size of homes

Traffic and congestion
Deterioration of natural beauty
Crowded conditions for water recreation
Noise from activities of people

Restrictions on use of pesticides
Restrictions on use of detergents
Further muffling of outboard motors
Limit on total number of seasonal homes
Restricted areas for trail bikes, etc.
Restricted zones for water skiing
Off limit areas for automobiles
Restricted zones for motor boating
Restricted time periods for water skiing
Restricted time period for motor boating
Restrictions on architectural design

Source number: 7, 27 and 126

## SELECTED UNDESIRABLE ESTHETIC QUALITIES

Too cluttered with buildings
Unesthetic
Skyline destroys view
Not good to look at
Signs
Cars too close to Bay
Tract houses
Signs

Salt flats
Swamps
Mud flats
Water too shallow
Too cold
Too rough

Not good for water skiing, fishing, swimming, sailing
Beaches inaccessible
Beaches unmanaged
Need more recreation areas

Fog
Smog
Humidity
Dampness
Windy

Port facilities antiquated
Industries dirty looking
Shoreline too industrialized
Too much Traffic
Freeways near Bay

Dissolved oxygen (DO)
Biological oxygen demand (BOD)
Temperature
Toxicity
Acidity
Alkalinity

Source number: 7, 27 and 126

## ADDENDUM

Several important references have been inadvertently omitted from the bibliography and the text of the report. These references are as follows:

Dornbusch, David M. & Co., Inc., Benefit of Water Pollution Control on Property Values, San Francisco, California, 1973.

Scaiola, G., "Public Intervention Against Pollution: Estimates of the Economic Costs and Benefits Related to a Project for Eliminating the Principal Forms of Atmospheric and Water Pollution in Italy," Rapportio di Sintesi, pp. 137-173, June 1971.

Tihansky, Dennis P., "Economic Damages from Residential Use of Mineralized Water Supply," Water Resources Research, 10, (4) pp. 145-154.

The first of the above references, i.e., Dornbusch and Co., is the only property value study that includes estimates of national property value benefits accruing from water quality enhancement. This reference should be included in the bibliography and in Section IV of the report.

The last reference, i.e., Tihansky, provides estimates of the economic damages from residential use of mineralized water. This important reference should be included in Section VI of the text and the bibliography.

At the present time DPRA has not had the opportunity to review the work by Scaiola. Various reviewers have, however, studied the article and recommended that it be included in the bibliography.